NOTES

FOR

A HISTORY OF LEAD.

NOTES

FOR

A HISTORY OF LEAD

AND AN INQUIRY INTO THE DEVELOPMENT

OF

THE MANUFACTURE OF WHITE LEAD AND LEAD OXIDES

COMPILED BY

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PREFACE.

This compilation is the result of a promise to a friend to prepare a paper upon the History of Lead, to be read at a social meeting of a trade club. My interest in the subject persisted after the paper was prepared, and I continued to collect notes, at such times as a busy man of affairs could spare, with no purpose or plan other than to gratify a thoroughly aroused interest in the subject, and as a relaxation and a relief from the friction and perplexities of business.

Le Febvre, in his "Compendious Body of Chymistry," published early in the seventeenth century, says: "Lead is the vilest and most abject of metals;" and book-makers generally have entertained as mean an opinion of it. They have treated its chemistry and metallurgy exhaustively, but its history seems to have been neglected, as I have been unable to find a work devoted to this subject, or even a satisfactory historical sketch in such technological works as have come under my observation. I have been tempted, therefore, to put into permanent form a summary of the notes I have collected. In my researches I found some interesting material relating to the manufacture of white lead, and was led to investigate the development of the practice of one of the earliest known

chemical processes. The results of my inquiries in this direction I have added, together with some notes upon the early use of lead oxides, and the methods employed in their manufacture.

I have wished to give full and proper credit for all facts and statements cited, and have tried to do so. But possibly some inaccuracies or omissions have been occasioned by the desultory manner in which the work has been compiled, and my absence from home during much of the time that the work has been in the hands of the printer, with the consequent inability to verify references.

With these explanations it may be proper, perhaps, for me to suggest that this compilation be considered as merely an enlargement or an amplification of the article prepared as an after-dinner paper for a paint club.

WILLIAM H. PULSIFER.

St. Louis, December, 1887.

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A HISTORY OF LEAD.

CHAPTER I.

INTRODUCTION.

ALL primitive nations who attained to any notable degree of civilization and political advancement had a knowledge of, and used, some of the more common and widely distributed metals.[1] There is little trustworthy historical information regarding the chemical and metallurgical processes by which metals were gained from their ores in ancient times; but the early Egyptian monuments present pictorial descriptions of smelting, and the earliest written records extant mention the results of metallurgical operations in a manner which clearly shows that these processes had long been known. It is possible that the writers of such works treating upon scientific subjects as have come down to us were acquainted with the results only of the ancient metallurgists, and not with the methods employed by them; it is possible also that the information we seek was contained in works which have been lost.

It is impossible, therefore, to assign any period for the discovery of metals. They have undoubtedly been independently discovered by many peoples and at various

[1] Lenormant, quoted by Bapst, declares that the Chinese, in the time of Yu (2000 B. C.), were acquainted with all the metals. See "L'Orfèverie d'étain, par Germain Bapst, Revue Archéologique," vol. xliii.

times. Some have been discovered and forgotten, rediscovered and forgotten again, by people of the same nation, and have received new names at each new discovery.

The remarkable properties of metals excited the superstition of primitive man, and their origin and discovery were frequently attributed to supernatural causes. Every early nation had its myths to account for these phenomena. The ancient Egyptians accorded the honor of the discovery of metals to their first sovereigns. The Phoenicians attributed this discovery to their heroes.[1] Pliny declares that gold mines, and the method by which gold may be fused, were discovered by Cadmus the Phoenician, or by Thoas, or Eaclis in Panchaia, or by Sol the son of Oceanus.[2] Aeschylus ascribes the invention of metals to Prometheus. Aristotle declares that some shepherds in Spain having set fire to the woods and heated the earth, the silver that was near the surface melted and flowed together in a heap, and that a little while after there happened an earthquake which cleaved the earth and disclosed a vast quantity of silver. This fable is alluded to by Strabo,[3] and Lucretius thus describes a similar phenomenon : —

> "Whatever 'twas that gave these flames their birth,
> Which burnt the towering trees and scorched the earth,
> Hot streams of silver, gold, and lead, and brass,
> As nature gave a hollow proper place,
> Descended down and formed a glittering mass."[4]

The God of the Sun — the Helios of the Greeks, and Sol of the Romans — was accredited with the discovery of

[1] De Goguet, The Origin of Laws, Arts, Sciences, and their Progress among most Ancient Nations (3 vols, Edinburgh, 1761), vol. i. p. 141.

[2] The Natural History of Pliny (Bohn's edition, 6 vols., London, 1855), book vii. chap. lvii.

[3] Strabo's Geography (Bohn's edition, 3 vols., London, 1854), book iii. chap. ii.

[4] Lucretius (Creech's translation, London), vol. ii. p. 572.

the art of metallurgy, and with the power of producing and controlling gold, with which metal his name has always been associated.

The testimony of ancient writers points to the far East as the source of their knowledge of the metals, and of the arts and sciences. The Egyptian, Assyrian, and Babylonian monuments bear evidence that at a very remote period those nations had acquired great wealth and power, and had attained a high degree of civilization. They prosecuted mining operations upon an extensive scale, were acquainted with many metallurgical processes, and reached a very considerable degree of perfection in the art of working metals.

The Hebrews seem to have gained their scientific knowledge from the Egyptians. They mention in their writings the same metals, and probably were only acquainted with the scientific methods acquired during their residence in Egypt.

The Phoenicians, according to fabulous history, originated in the country bordering upon the Indian Ocean. Driven from their land by an earthquake, they settled upon the shores of the Mediterranean before the time of Abraham, and founded the cities of Sidon and Tyre. They were bold sailors, and the first navigators to undertake long voyages. They steered their barks at night by the constellation of the Little Bear; and their nautical skill has been considered as evidence of their astronomical knowledge, the origin of this science, as well as of arithmetic, has been attributed to them.[1]

In obedience to an oracle which, Strabo says, commanded the Tyrians to found a colony by the Pillars of Hercules,[2] the Phoenicians, as early as 1100 B. C., pushed

[1] Pliny, book vii. chap. lvii. See also "Historical Survey of the Astronomy of the Ancients," by Sir Geo. C. Lewis. London, 1862, p. 447.

[2] Strabo, book iii. chap. v.

into the Atlantic, and coasting along the shores of Spain, landed and founded a settlement which they named Gadir, called Gades by the Romans, meaning literally "a refuge," the site of the modern city of Cadiz. An extensive trade was at once established with the natives, who possessed great stores of gold, silver, copper, and lead. The country in the neighborhood was gradually subdued, settlements were made in the interior, and they soon had the entire control of the valuable trade of Iberia and Lusitania, — the countries now known as Spain and Portugal. The metals, so abundant in those countries, were easily procured, and became the source of great wealth and power.

The Phoenicians also founded Carthage and other colonies on the Mediterranean; they traversed the Aegean Sea, and established settlements at every point convenient for mining and trading.

The Carthaginians succeeded their ancestors, the Phoenicians, in the possession of the mines of Spain. They formed settlements along the shores of the Mediterranean, and beyond the Pillars of Hercules, to connect the parent colony with the settlements in Iberia, and thus insure their supremacy. In the time of Diodorus the Carthaginians encouraged mining enterprises, and were accredited with having opened all the mines then known.[1]

Iberia was unknown to the Greeks until the fifth or sixth century before Christ, after this period they contested with the Phoenicians for the possession of that country and its valuable commerce. The fall and destruction of Tyre (573 B. C.) was followed by the gradual decline of the Phoenician colonies and the rise of Greece and Rome.

[1] The Carthaginians are said to have erected a temple to Aletes, who discovered some valuable mines. A. H. HEEREN: Ancient Nations of Africa (Oxford, 1838), vol. i. p. 151.

The early inhabitants of Greece were a rude and barbarous people, living in caves, clothed in the skins of wild beasts, at perpetual war with each other, and, owing to the inhospitable character of a portion of their country, they were often driven to such straits for want of food that cannibalism was not infrequent.[1]

A colony from the East is said to have made a settlement in Greece about the time of Abraham, but it was not of long duration. De Goguet says the civilization of that country dates from the foundation of colonies by the Phoenicians and Egyptians at a later period. Schliemann found evidences of Phoenician and Egyptian influences[2] in the decoration of the pottery of ancient Argos, in the legends illustrated in some of the antiquities discovered at Mycenæ and at Tiryns, and in the methods employed in the construction of the walls and buildings. But Grote, while he admits that traces of Phoenician settlements may be found in some of the Grecian Islands, sees no proof for probable inference that the Egyptians and the Phoenicians settled in continental Greece. Be that as it may, these early Greeks were an enterprising people; but their activity seems to have been directed more to conquest and to the extension of their political power than to commerce and the peaceful arts. They conquered the countries bordering upon the Aegean Sea, and founded colonies, but for many centuries the arts and sciences made little progress with them.[3]

Rhodes, a Greek colony, very early became the seat of a high civilization. The Rhodians were long masters of the sea, and became allies of the Romans. They excelled

[1] De Goguet, vol. i. p. 64. See also Pliny, book vii. chap. lvii. See also A. H. L. Heeren, Historical Researches into the Politics, Intercourse, and Trade of the Principal Nations of Antiquity (Oxford, 1833), vol. ii. p. 37.

[2] Schliemann (Tiryns, New York, 1885), pp. 21, 28.

[3] See Grote's History of Greece (12 vols., London, 1851), vol. ii. p. 357 *et seq.* Also De Goguet, vol. i. p. 65 *et seq.*

in the arts and sciences, and their manufactures became famous throughout the civilized world. Homer bears testimony to the early prosperity of the Rhodians, and says: "They were the beloved of Jupiter, who poured abundant riches on their new abode."[1] Strabo says of the city of Rhodes: "Its harbors, roads, walls, and other buildings, so much surpass other cities that we know of none equal to it."[2]

The Greeks in Strabo's time had made great advances in science, and appear to have acquired more accurate information regarding the general constitution of metals, and to have given the names to many metallic substances by which they are known to-day.[3]

There are many references to metals in the Old Testament, but the statements regarding metallurgical processes are vague and obscure, and there is reason to believe that early translators often substituted the name of a metal known to them when in doubt respecting the metal mentioned in the text. The works of early profane authors frequently contain statements regarding metals which, in the light of modern science and experience, appear inaccurate and unacceptable.

The metals known to the Egyptians, Hebrews, Phoenicians, and other early nations, were gold, silver, iron, copper, tin, and lead. The Greeks and Romans, about the beginning of our era, knew the metal quicksilver, but it is impossible to say when it was discovered; its ore, cinnabar, had long been known and used as a pigment. Pliny and Dioscorides, in the first and second centuries, describe it accurately and mention its use in purifying gold. Dioscorides suggests a process for recovering it from its ores.

[1] Iliad, Bryant's translation (Boston, 1875), vol. i. p. 857.

[2] Strabo, book xiv. chap. ii.

[3] Dr. H. Kopp, Geschichte der Chemie (Braunschweig, 1843, erster Theil), p. 19.

The Romans at this time were acquainted with the oxides and chlorides of several metals, and their methods of preparing them differed but little from those in use to-day.

It is extremely probable that gold was the first metal known to man. It is more commonly found pure in nature than any other metal, and more easily procured, often occurring in the beds of streams, — where it has been carried after being freed from its matrix by the decomposition of the rocks in which it was originally deposited, — and in the gravel with which the beds of ancient rivers are often filled. Its power to resist atmospheric influences tends to preserve its rich color; this characteristic, together with its great weight, must have attracted the attention of primitive man. All ancient accounts point to this conclusion; indeed, in some countries, when silver was first discovered it was called "white gold."[1] Copper is also found pure in nature, and was known and extensively used at a remote period. Silver is more rarely found native than either gold or copper, and in very early times was more valuable than gold. Lead is very rarely found pure in nature, never in considerable quantities. Pliny says that lead was discovered by Midas, King of Phrygia, who is also accredited with having been the first to procure tin from the Cassiterides;[2] but as lead is produced in the extraction of silver from some of its more common and abundant ores, it is probable that its discovery was coeval with that of silver.

Lead received many names in antiquity. It was known at a remote period, and being of little importance and rarely used, it was probably forgotten by those who found no use for it, and received a new name upon being rediscovered and utilized. According to Pictet, it has as many

[1] Popular account of the Ancient Egyptians, by Sir J. Gardner Wilkinson (London, 1874), vol. ii. p. 147.

[2] Pliny, book viii. chap. lvii.

as thirty names in Sanskrit, several of which it bears in common with tin. Tin is sometimes called in Sanskrit "kurupya," meaning bad silver, while one of the names of lead is "kuranga," or bad tin. Another name for lead noticed by the same author is "bahamala," from "baha," much, and "mala," dirt or filth, whether because lead soils the hands when touched, or because it left a heap of scales after fusion, he is unable to say.[1] In India the name for lead is "mulva." The province of Malava is said to have received its name because it furnished much lead. The Greek name "molybdos" was probably derived from the Indian name; this circumstance has led some authors to maintain that the knowledge of the metal came from the East.[2] The Persian name for lead is "surb;" in Arabic it is "anuk;" in Hindostani, "sisa;" Russian, "swinetz;" Polish, "olow;" in Spanish, "plombo;" in Italian, "piombo;" in Dutch, "loot" or "lood;" German, "blei;" in French, "plomb;" Danish and Swedish, "lod;" in Anglo Saxon, "lead."

The only instance of the occurrence of lead in the ruins of ancient Egypt mentioned by Wilkinson is its use in soldering. The date of the oldest specimen observed by that author is pronounced to be uncertain, but he ascribes it to the time of the Pharaohs.[3]

There can be no doubt that silver in ancient times, as at the present day, was largely procured from argentiferous lead ores. The method of separating gold and silver from other metals, and of refining and purifying the noble metals by the use of lead, are referred to or described in the Old Testament, and by Agatharchides, Pliny, and other

[1] Les Origines Indo-Européennes. Adolph Pictet. Paris, 1859. Lead is not mentioned in the oldest Sanskrit book, the Rig Veda, but it is spoken of in the Artharva Veda.

[2] The Metallurgy of Silver and Lead, by Robt. H. Lamborn, Ph. D. (London, 1874), p. 16.

[3] Wilkinson, vol. ii. p. 362.

ancient writers. As lead was considered of little value, or indeed but the dross or natural impurity of the ores of silver, the refining or separation of the silver was usually conducted near the mines, thus saving the cost of transportation of the greater part of the ore, and that portion which was of little or no value. This has been the custom through all historic times when the mines have been situated in districts at all inaccessible. In our own day, at some of the Mexican mines which are remote from railway or other means of cheap transportation, the litharge, or protoxide of lead, one of the products of refining argentiferous lead by the ancient process of cupellation, is left in heaps, as waste or refuse, and not of sufficient value to transport on the backs of mules, or of porters, or by other crude and expensive methods to market. In the early days of mining in the Rocky Mountain districts, before the completion of the Union Pacific Railway, the silver was recovered at the mines by cupellation, and the lead, in the form of litharge, was cast aside and accumulated in great piles, the silver alone being able to bear the cost of carriage. Accumulations of litharge have been found near ancient smelting-places in the Ural mountains, in Spain, in Portugal, and at other seats of ancient mining.

It will thus be seen that the history of lead is intimately connected with the history of silver, and in the absence of particular accounts and descriptions of the occurrence, and of the mining and metallurgy of lead in early times, we are obliged to examine the history of silver, as found in the works of ancient writers.

In Egypt gold was evidently known before silver, as at first silver was called white gold. By the laws of Menes gold was worth two and one half times as much as silver, thus at that early period the process of extracting silver from its ores, and its purification, must have been known, and consequently the substance litharge,

or protoxide of lead. Silver was used in very early times as money. The Hebrew word "kussuf," meaning silver, was also used to signify money, as the French word "argent," signifies both silver and money to-day.[1] Gladstone refers to a passage in Homer which seems to imply that silver was only obtained at Alubé, in Asia Minor.[2]

The Israelites are commanded by Moses to purify the gold, silver, brass, iron, tin, and lead taken from the Midianites, by passing it through the fire.[3] This passage contains the first allusion to lead found in the Bible; but silver is mentioned in describing the wealth of Abraham, who was very rich in cattle, in silver, and in gold;[4] and again when Abraham agreed with Ephron for his field, and weighed out to him four hundred shekels of silver, current money with the merchants.[5] Gold and silver, therefore, were used as money in the time of Abraham, and it is probable that lead also was known, and that the art of metallurgy had attained considerable perfection. According to Wilkinson, gold is represented on the ancient Egyptian monuments dating from the fourth dynasty, and he says that silver was probably known at as early a period.[6]

It is not surprising that the appearance of the sun above the horizon and its passage across the celestial arch should have created a profound impression upon the mind of primitive man; no less impressive, perhaps, was the course of the moon and of the planets among the stars, and we can understand the feelings which prompted the mythologies of ancient Egypt and of other primitive nations.

[1] Wilkinson, vol. ii. p. 147.

[2] Juventus Mundi, by W. E. Gladstone (London, 1870), p. 532. Silver was much more common in Homer's time than this statement would lead us to suppose; besides, Strabo commented upon the passage referred to by Gladstone, and altogether discredits the existence of Alubé. Strabo, book xiii. chap. i.

[3] Numbers, v. 22, 23. [4] Genesis, xiii. 2. [5] Ibid. xxiii. 16.

[6] Wilkinson, The Ancient Egyptians, vol. ii. p. 240.

The Egyptians gave to the sun, moon, and planets the names of the divinities they wished to distinguish; the Greeks, it is supposed, adopted these Egyptian names. The American aborigines very generally venerated and worshipped the nearer celestial bodies, and attributed to them an animate existence; each tribe had its special myths, and gave names to such heavenly bodies as it held most in veneration. The Chinese recognized five elements, earth, fire, water, wood, and metals. To these they gave the names of the five planets: to the earth, "Saturn;" to wood, "Jupiter;" to fire, "Mars;" to metals, "Venus;" to water, "Mercury.[1] At a very remote period there was thought to be a connection betwen the metals and the planets, and in the works of many ancient writers the names of the planets are applied to the metals. The alchemists adopted the practice, and observed the following classification: to gold, they gave the name of the "Sun;" to silver, the "Moon;" to tin, "Jupiter;" to iron, "Mars;" to copper, "Venus;" to mercury or quicksilver, "Mercury;" and to lead, "Saturn." They used the names and the astronomical signs of the planets, in their writings, to designate the metals.

The oldest trace of the division of the metals among the gods occurs in the religious worship of the Persians. The revolution of the celestial bodies was represented by this people by seven stairs, which conducted to the same number of gates; the first gate was of lead, the second of tin, the third of copper, the fourth of iron, the fifth of a mixed metal, the sixth of silver, and the seventh of gold; the leaden gate had the slow tedious motion of Saturn; the tin gate had the lustre and gentleness of Venus, etc.[2] A transposition in some of the names was made at a later

[1] De Goguet, vol. ii. p. 420.

[2] History of Inventions, Discoveries, and Origins, by John Beckmann, translated by William Johnston (London, 1883, 2 vols.), vol. i. p. 25.

period; but, whatever the transposition, ancient writers agree in giving to lead the name of Saturn. It is probable that in all times a resemblance has been traced between the dull, cold-colored metal and the more remote and slow-moving planet. It has been suggested that the supposed connection between the planets and the metals resulted from the fact that the number of metals known in early times was seven (brass was sometimes referred to as a simple metal), — the sacred number of the Egyptians, Persians, and other ancient nations, while the sun, moon, and the five planets recognized in those days, also made the number seven.

Boerhaave says: —

"Chemists have now adapted the names of the planets to the metals, according to the nature of their bodies.

"✠ Denotes whatever is acrid or corrosive, as vinegar, fire, etc., as if furnished with sharp spikes.

"☉ Something perfect, immutable, most simple, as gold, which contains nothing acid.

"☾ Half gold, whose inside turned outside makes perfect gold, without anything exotic or corrosive. This the alchemists observe of silver.

"☿ The inward part to be pure gold; but the color of silver above, with a portion of acrid and corrosive at bottom. This alchemists have observed of mercury.

"♀ The principal part to be gold; but a crude and corrosive acid adheres to it, which, when separated, leaves the rest with all the properties of pure gold. This also the adepts assert.

"♂ Also gold within; but a considerable portion of corrosive acid.

"♃ One half of tin is silver, and the other a crude corrosive antimony.

"♄ Almost all corrosive, with some similitude of silver. This hint to the skilful is sufficient." [1]

[1] Herman Boerhaave, M.D., Elements of Chemistry, translated by a gentleman of the University of Oxford (London, 1731), vol. i. p. 24 *et seq.*

A writer of the middle of the seventeenth century says: —

"Those who believe the stars have an influence over sublunary things attribute the formation of precious stones to the superintendency of the fixed stars, who seem to imitate them not only in their brightness and lustre, but in the purity and permanency of their substance; whereas metals, for their instability and alteration of form, being sometimes liquid, at other times solid, they assign to the particular government of the planets, who, from the variety of their motions, are called wandering stars."[1]

Lead (or Saturn, as they termed it) was one of the most important elements in the experiments of the alchemists. Its high specific gravity and its low melting point constantly enticed them to attempt its conversion into the substance which should transmute the baser metals into gold.[2] They considered it to be the oldest of the metals, and so named it Saturn, in honor of the oldest, and consequently the father of the gods. In the process of cupellation, or refining the noble metals, lead, if not already present in the alloy, is added, and in the operation is said to liquify other base metals which may be present, and, as the ancients believed, to consume and destroy them, as Saturn in fabulous history is said to have devoured his own children. Boerhaave says: "As Saturn, in all ancient mythologies, is considered to be the father of the gods, so lead is the father of the metals, and at the same time is their destroyer."[3] The alchemists and the earlier writers on chemistry unite in ascribing to lead a heavy, cold, and sometimes wholly repulsive nature. Bacon says lead is cold and dry.[4] Encelius describes

[1] First Book of the Art of Metals, by A. Barba, translated by the Earl of Sandwich (in a collection of scarce and valuable treatises upon metals, London, 1738), p. 60.

[2] Geschichte der Metalle, by Dr. F. X. M. Zippe (Wien, 1857), p. 197.

[3] Boerhaave, Elements of Chemistry, vol. i. p. 24.

[4] Fr. Roger Bacon, Opera Inedita, edited by J. S. Brewer (London, 1859), p. 380.

lead, or Saturnis, as the cold son of sulphur and quicksilver,[1] while Le Febvre declares that "lead is called Saturn by reason of its sympathy with that planet, as also its relation to the spleen, which is called the Saturn of the microcosm, to which it is dedicated."[2]

However absurd the experiments and the opinions of the alchemists may appear when viewed in the light of modern science, we are indebted to their researches for the establishment of the science of chemistry upon a substantial basis, as their attempts to find the elixir of life and the philosophers' stone led to a more complete knowledge of the chemical elements.[3]

The Greek poets used the term "Saturnian" to describe coldness, and represent Saturn as an old man and slow in his motions. More modern poets constantly use the figure lead to describe coldness, slowness of motion, etc.: —

> "If thou dost find him tractable to us,
> Encourage him, and tell him all our reasons;
> If he be leaden, icy cold, unwilling,
> Be thou so too."
>
> RICHARD III., ACT III., Scene 1.

[1] Christophoro Encelio, De Re Metallica (Frankfort, 1557).

[2] A Compendious Body of Chymistry, by N. Le Febvre, Royal Professor in Chymistry to His Majesty of England, and Apothecary to His Honorable Household. Rendered into English by P. D. C. Esqr., one of His Majesty's Privy Chamber (London, 2 vols., 1664), vol. ii. p. 183.

[3] Zippe, Geschichte der Metalle, p. 197.

CHAPTER II.

THE LEAD MINES OF ANTIQUITY.

IN ancient times Egypt possessed great stores of the precious metals, obtained partly from her own mines and partly received as tribute from conquered nations. Early writers refer to the gold mines of Nubia and Ethiopia, but fail to mention the location of the mines from which Egypt procured her silver. Lead and iron mines were exploited in the desert near the Red Sea;[1] the lead mines yielded an argentiferous ore, from which the silver was recovered, but it is probable that the supply of silver was principally obtained from the conquered nations who paid tribute in this metal.

The tributes paid to Thotmes III. by Asiatic peoples and by Southern Ethiopians consisted principally of gold; the Assyrians, however, in addition to gold, paid tribute in silver in the form of rings, and in copper and lead cast in the shape of bricks, or pigs, to use the modern term; sometimes they brought the ore itself. The mountains of Assyria abounded in iron, copper, silver, and lead.[2]

There is little to be said of lead at the time of the ancient Egyptians; it was undoubtedly known to them, as was its protoxide, litharge, — a by-product in the recovery of silver from argentiferous lead ore; and the

[1] Wilkinson, vol. ii. p. 239.

[2] Nineveh and its Remains, by A. H. Layard, D.C.L. (New York, 1849, 2 vols.), vol. ii. p. 316.

only evidence discovered of its use was in soldering and in the glazing of pottery.[1]

Ruins of old mining stations can still be traced at Kohel, near the Red Sea, and at Jabal Rossas, literally "the mountain of lead," where mines were exploited by the ancients. Vestiges of ancient silver and other mines have been found in the country of the Bejahs, between Eidub and Suakin. The Pharaohs made war against the predecessors of this people — the ancient Blemmies — for the possession of these mines.[2]

The ores of lead are widely distributed over Asia. Traces of ancient mining have been found in the mountains of Waisti-Karu, near the Oxus. The greater part of the silver in Persia came from the mines of Bucharia and Aderbijan. Bactriana anciently possessed silver mines of great depth, and the Chalybeans, referred to by Homer, says Heeren, were at all times engaged in mining; some of their silver mines were worked in the time of Xenophon, though they were then thought to be nearly exhausted.[3]

Lead ores are found at Oinan and Ras-al-Had and other parts of Arabia; valuable mines occur in many parts of the Burmese Empire, and in the mountains of Baluchistan. In Armenia and Chaldea silver lead mines were worked by the ancients, and, according to Leger, silver was so abundant in ancient times in China, India, Persia, Judea, and Phoenicia, that it was used for weapons, and in some cases even for agricultural implements.[4] Silver mines were worked in the Caucasus in remote antiquity; mines of argentiferous lead ore were worked in

[1] See Wilkinson, vol. ii. p. 162; also Ancient Workers and Artificers in Metal, by James Napier (London, 1856), p. 128.

[2] Heeren, Ancient Nations of Africa, vol. ii. p. 333.

[3] Heeren, Historical Researches (Oxford, 1833), vol. i. p. 49.

[4] Les Travaux Publics les Mines et la Métallurgie aux Temps des Romains, etc., par Alfred Leger (Paris, 1875), p. 713.

Siberia, near the southern border of the Ural Mountains, as early as 150 B. C., as at that time the country was conquered by the Tartars, who were acquainted with the use of iron; the old miners used sledges and hammers of stone, and the teeth of wild animals fastened to a stick, for excavating shafts, which, in some cases, were more than a hundred feet in depth. The ore was treated at the mines, and the silver recovered, while the litharge was abandoned as valueless.[1] Lead occurs in Kurdistan; and Marco Polo refers to many lead and silver mines noticed by him in Asia, the most remarkable being in the neighborhood of Beyert, and in going from Trebizond to Tauris. He also mentions lead mines in Badashan, and in Northern China.[2]

Modern explorers have found vestiges of ancient exploitation of lead mines in Africa, particularly in Tunis and Algeria, where the ores occur in some abundance.

The Phoenicians were noted for their skill in excavating and mining, and this enterprising people, in very early times, scoured the countries bordering upon the Mediterranean in search of metals, founding colonies on every coast and island favorable for mining and trading. They worked lead mines in Cyprus, and in many islands of the Aegean Sea. Herodotus, referring to their mining operations in Thasos, says: "A huge mountain has been turned upside down in search for ores."[3]

The earliest mining in Greece of which we have records was at Laurium.[4] These mines were famous in ancient

[1] Histoire Généalogique des Tartares, quoted by Phillips and Darlington, Records of Mining and Metallurgy (London, 1857), p. 16; also Heeren, Historical Researches, vol. i. pp. 42, 47.

[2] The Book of Marco Polo, translated by Yule (London, 1871, 2 vols.), vol. i. p. 45.

[3] Geo. Rawlinson, The History of Herodotus (New York, 1872, 4 vols.), vol. iii. p. 367.

[4] Pausanias, Description of Greece, translated by Arthur R. Shilletto (London, 1886), vol. i. p. 1.

times for their deposits of argentiferous lead ores, which are said to have supplied ancient Greece with the principal part of her revenues. Leger thinks they were worked as early as the Trojan war, and perhaps before, supplying foundries at Thonea, Cypriano, and at other places.[1] It is said that twenty thousand slaves were once employed in them. They were thought to be exhausted at the beginning of our era, as Diodorus says of them: "They that search there for ores are at great cost and charge, and besides are often frustrated of their hopes, and sometimes lose what they have found."[2] These mines were reopened in 1863 by a French company, and have been worked continuously since that time, the ore and base bullion being sent to France for treatment. The old slag and scoriae left by the ancient miners have been reworked by a French and a Greek company, and have yielded rich results. The mines at Damastium, in Epirus, and those near Paeonia, were opened about the time of the Persian war, and continued to be worked in Strabo's time.[3]

There is little to be found in the works of ancient writers concerning mining in Greece in early times. The reigning princes, Jacob thinks, were the chief owners of the mines; the condition of society at that period was such as would make it impossible to carry on these works except by the employment of slaves, whose numbers were the standard by which the wealth of the chiefs was estimated. Later, the mines were the property of the community, and were leased to private individuals.[4]

The ancient miners probably smelted only the ore found near the surface, and their methods of refining were con-

[1] Leger, Les Travaux Publics, etc., p. 702.

[2] The Historical Library of Diodorus the Sicilian, translated by G. Booth (London, 1814, 2 vols.), vol. i. p. 319.

[3] Strabo's Geography, book viii. chap. vii.

[4] Wm. Jacob, F.R.S., An Historical Inquiry into the Production and Consumption of the Precious Metals (London, 1831, 2 vols.), vol. i. p. 71.

sidered crude as early as Strabo's time, who informs us that they were unable to properly separate the silver from the lead, and that those who came after them reworked the refuse with profit.[1]

There was very little mining in Italy in ancient times; minerals occurred in many districts, but in very early days the exploitation of mines was prohibited by a decree of the Senate, — "but whether," Pliny says, "to keep the treasure in reserve, or to prevent an indignity to her soil, does not appear."[2] At a later time another edict prohibited the employment of more than three thousand miners in the mines of Irtimule, near Vercellae. The Romans pushed mining operations in all conquered countries with great vigor; but they seem to have exhibited a desire to reserve the mineral wealth of their own country. Mines of lead and silver exist in the Italian Alps, and in Piedmont, which were worked in ancient times and in the middle ages.

Sardinia was the seat of extensive mining operations in very early times. Her mines were first worked by the Phoenicians, then by the Carthaginians, and afterwards by the Romans. Modern travellers have discovered the ruins of many ancient foundries and furnaces, and vestiges of excavations of vast extent. Among many relics of ancient works found in Sardinia in modern times is a pig of lead, weighing about seventy pounds, and inscribed with the name of the Emperor Hadrian.

Vestiges of ancient lead mining have been discovered in Sicily. An old mine on the ancient Cape Peloris was reopened in 1747, but abandoned a few years later.[3]

Ancient writers tell us that it was the mineral wealth of the Iberians which excited the cupidity of the Phoenicians, and led to the subjugation and settlement of Spain by

[1] Strabo's Geography, book ix. chap. i.
[2] Pliny, Natural History, book iii. chap. xxv. and note.
[3] See C. J. B. Karsten, System der Metallurgie, Berlin, 1831.

that wonderful people. Soon after the founding of Gades settlements were made by the Phoenicians at other places, notably Malacca, the modern Malaga, Carteia, and Hispalis, the modern Seville; until within a comparatively short period they had planted more than two hundred colonies, and in the sixth century B. C. had complete possession of the country. The original inhabitants were soon subdued, and forced to work in the mines under such harsh and cruel treatment, Diodorus tells us, "that they died in the caverns they had themselves dug."[1] The Carthaginians were famous freebooters and slave-traders, and making incursions into Africa took great numbers of captives to replace the aboriginal inhabitants who had been destroyed by the great hardships imposed upon them. The almost fabulous amounts of silver carried in triumphal processions in Rome, by the conquerors of Spain, attest the richness of the mines, and the great extent of their exploitation by the Carthaginians.[2]

It is probable that the first mining occurred at the foot of the Sierra Morena, and near the banks of the Guadalquivir, by which the products could be conveyed to Hispalis. Argentiferous lead ores were mined in the neighborhood of Cartagena, at Ilipa, Sisapon, Barcelona, Almeria, Castellon, and in Lusitania.[3] Ancient writers refer in extravagant terms to the mineral wealth of Spain. Strabo says, "A chain of mountains running parallel to the Guadalquivir is rich in metals;" and again, "The whole country of the Iberians is full of minerals."[4] According to Diodorus, "those that worked the mines of Iberia were greatly enriched, for they succeeded at the very first, the whole soil being interlaced with metals."[5]

[1] Diodorus, vol. i. p. 321.
[2] See Livy's History of Rome.
[3] Jacob, The Precious Metals, vol. i. p. 95; also Leger, Les Travaux Publics, p. 698.
[4] Strabo's Geography, book iii. chap. ii.
[5] Diodorus, vol. i. p. 319.

Pliny frequently refers to the great mineral wealth of Spain, and regards it as a remarkable fact that the mines opened by Hannibal should still be worked. He says: "Where one vein of mineral occurs a second is sure to be found near it, — a circumstance which suggested the name 'metals,' from the Greek word 'metalla,' signifying 'one after another.'"[1] Strabo, quoting Polybius, says that the silver mines of New Carthage were very large, and that forty thousand men were constantly employed there. He also informs us that at Castellon, and at other places, lead mines were worked the ore of which carried so little silver that the separation of it was unprofitable.[2]

The numerous vestiges of ancient mining found in the mountains of Northern and Central Asia, in Europe, and in Africa, make it apparent that the search for metals was pursued to a much greater extent than the scattered and fragmentary mention of it by ancient writers indicate. The Egyptians, Phoenicians, Persians, and other ancient nations possessed vast stores of the precious metals, and used them in great quantities in the decoration of their persons, their garments, their furniture, and the housings of their horses and their equipages. The same greed for the possession of gold and silver obtained in ancient times as prevails to-day. Lead is very rarely referred to in ancient writings, but the amount of silver in existence makes it evident that lead was produced in large quantities, principally as a secondary product in the extraction of silver from its ores, and in amount far beyond the needs of the times. It was regarded as of little value, but notwithstanding the evidences of its economic employment are meagre in the extreme, there can scarcely be a doubt of its general and extensive use. Its increased value in modern times is the result of a more general

[1] Pliny, Natural History, book xxxiii. chap. xxxi.

[2] Strabo's Geography, book iii. chap. ii.

employment, demanded by the needs of a more refined civilization.

Intercourse and trade in remote antiquity were quite extensive. The Egyptians traded with Ethiopia for gold, ivory, and slaves; with Arabia for incense; with India for spices; with Greece and Phoenicia for wine; and with African nations for salt. The Chaldeans, Assyrians, and Babylonians had an extensive trade with other Asiatic nations and with India. The Phoenicians, the great merchants of antiquity, had control of the trade of the Mediterranean, of the countries of Africa bordering upon the Atlantic, of Lusitania, of Gaul, of Britain, and it is claimed that they traded for amber with the countries on the Baltic. The land trade of the Phoenicians was through Arabia, the great seat of their caravan trade, by which they made their exchanges with India; while in the south they penetrated to Ethiopia and Central Africa.[1] Through this intercourse and trade, considerable as they undoubtedly were, the metals were distributed among the early nations. The gold of Ethiopia found its way to the inhabitants of Asia; the silver of Siberia was common among the treasures of the Assyrians; the tin of India, and of far-away Britain, was combined with the copper of Cyprus to form the bronze of the Egyptian; and the lead mined by the ancient Briton was exchanged with the Phoenician merchants for the manufactures of the Asiatic and African nations.

The enormous booty acquired by the Romans in their victories over the Carthaginians directed their attention to one of the sources of the wealth of that nation, the mines in Iberia. After the fall of Carthage they prosecuted mining operations in Spain with great vigor. The

[1] Heeren, Historical Researches, etc., vol. i. p. 48; vol. iii. p. 111. Heeren also directs attention to the account of the trade of the Phoenicians described in Ezekiel xxvii.

inhabitants were expert in mining and metallurgy, and were forced by the Romans to build their fortifications and to work their mines. They founded a city in the Asturias, and called it Argentiola, on account of the vast treasure of silver produced there. They mined lead at Cartagena, Castellon, Barcelona, and at many other places.

Some archæologists insist that the Phoenicians and Gauls, before the conquest of France by the Romans, exploited the argentiferous lead mines of that country. This statement has support in the fact that in some cases the galleries of ancient mines were used by the Romans as sepulchres. Evidences of mining operations in France, during Roman occupation, are numerous. An iron pick, evidently of Roman manufacture, has been found in an ancient gallery of a lead mine near Villefranche, Aveyron. The find of Roman and Gallic pottery and Roman coins in a mine in Valence, is thought to prove that this mine was worked not only by the Romans, but by the Gauls previous to the conquest.[1] In a mine 100 feet deep, at Pontigibaud, Roman lamps have been found; in Savoy the galleries of an ancient mine bear Roman numerals. Pigs of lead bearing the names of Roman emperors have been found at Evreux, Lillebourne, and at other places in France, and have been regarded as additional evidence of Roman exploitation of the lead deposits of that country,[2] but the Abbé Cochet inclined to the belief that this lead was really the production of British mines; and he was supported in this view by an eminent authority who construed a partially obliterated inscription upon one of the pigs into the name of the British smelter; the Abbé also believed the Romans obtained all their supplies

[1] See Aperçu Historique sur l'Exploitation des Mines dans la Gaule, etc., par A. Daubrée.

[2] See Daubrée, Aperçu Historique, etc.; also Leger, Les Travaux Publics, etc., p. 715.

chariots, as the old Grecian heroes are said to have done in the Trojan war.[1]

Tylor directs attention to the law that metallurgical discoveries are made in districts where this art is practised, and says that the working of lead can scarcely be an exception; hence he concludes that the ancient Britons had considerable knowledge of the science of metallurgy. He also refers to the complete establishment of the tin industry at that remote period, and infers that the ancient Britons were also smelters of lead. He directs attention to the similarity in construction and design between the leaden mortuary and other relics found in England, Italy, France, and even in Sidon, and thinks this indicates a common origin; a further proof is offered in the fact that works in lead and bronze have frequently been found on the continent, as well as in England, bearing the names of British makers. Upon a leaden coffin discovered near Peterborough, England, and on a piece of lead pipe found near Lyons in France may be traced the names of the British manufacturers. This author concludes that the smelting and working of lead is an ancient British industry; that the Roman occupation was chiefly for the development of these arts to supply other Roman provinces; and that York — probably an old British city — was chosen as the northern capital on account of its

voyage he reached the mouth of the Garonne, found a road across Gaul, and reached Massilia in about a year from the date of his departure. Pytheas' account of his discoveries was violently attacked in ancient times by Strabo and Polybius. Sir George Lewis accepts the views of these old writers, in part at least, but other modern writers accord to Pytheas the honor of being the first navigator of northern British seas. The doubts thrown upon the narrative of Pytheas relate principally to his claim of having reached a high northern latitude; there is every reason to believe that he landed in Britain. See Strabo's Geography, book ii. chap. iv.; Rhys, Celtic Britain; Historical Survey of the Astronomy of the Ancients, by Sir Geo. C. Lewis, p. 46; Early Man in Britain, by W. Boyd Dawkins, p. 478; Lubbock, Prehistoric Times, p. 63.

[1] Diodorus, vol. i. p. 310.

proximity to the lead mines of Alston-Moor and southern Yorkshire.[1]

The lead deposits of Great Britain were exploited during the occupation of the country by the Romans with great vigor. In nearly every district where lead has been found in modern times there may still be traced ruins of old camps and fortified places, situated generally in close proximity to ancient shafts and galleries, and surrounded by great heaps of scoriæ and slag. In modern times examination of these piles of rubbish has disclosed Roman coins, tools, and implements of wood and of iron; knives, pottery, ivory and leaden spoons, and other articles for domestic use; brooches and metallic ornaments for personal adornment, besides other proofs in great variety and abundance of a long and uninterrupted occupation.

The metallic wealth of Great Britain was well known in the early days of our era, at which period it is probable the surface ores of Spain were exhausted. Pliny says: "Lead is extracted with great labor in Spain and throughout all the Gallic provinces, but in Britannia it is found in the upper stratum of the earth in such abundance that a law has been made prohibiting any one from working more than a certain quantity of it."[2]

The Romans began exploiting the lead mines soon after the conquest. Hunt, in his exhaustive work on "British Mining," describes in great detail the principal sources of supply, and the evidences of the working of British lead mines by the Romans. Ancient works have been traced in Northumberland and in Cumberland; there are vestiges of extensive mining in Yorkshire; in all parts of Derbyshire old waste heaps have been found consisting of slag, ashes, and bits of unconverted galena, from which modern

[1] Archæologia, vol. xlviii. (London, 1884), article by Alfred Tylor, p. 221 *et seq.*

[2] Pliny, Natural History, book xxxiv. chap. xlix.

smelters have obtained, by reworking, great quantities of lead; in Shropshire, Hunt says: "The Roman miners cut the mountain in their search for ore in deep grooves from top to bottom, filling up old excavations with the débris from the new." More than one district has been suggested as being the locality referred to by Pliny, where he speaks of the great quantities of lead in Britain.[1] The Mendipp Hills bear traces of many ancient workings, and the slags left by the Romans have furnished material for modern smelting for many years.

According to Pennant the town of Flint, in Wales, was once a Roman station. Roman coins, old instruments, and other antiquities found in the neighborhood, attest the fact; great heaps of scoriæ, containing bits of lead ore and fragments of melted lead, picks of extraordinary size, and buckets of singular construction, have been found in this and the neighboring parish of Northop, especially at "Pentre Ffwrn-Dan," a name it has always been known by, and meaning "the place of the fiery furnace." These, Pennant thought, are conclusive proofs of the antiquity of smelting in that district.[2] The tin deposits of Devon and Cornwall had been worked by the Britons for centuries before the conquest, and were undoubtedly exploited by the Romans, who at first employed the conquered inhabitants in these, as well as in their lead mines, guarded and directed by Roman soldiers. The mines of Britain were probably worked for the emperors, as was the case in other conquered provinces.

British authors refer to many seats of Roman mining in England and Wales; and it is evident that the mining of

[1] British Mining, Robert Hunt, F.R.S. (London, 1884), p. 27 *et seq.* See also Britain, or a Chorographical Description of the most Flourishing Kingdoms, England, Scotland, and Ireland. Written first in Latin by William Camden, Clarenceaux King of Arms; translated newly into English by Philémon Holland, Doctor in Physick, etc. (London, 1610), p. 556.

[2] Pennant, A Tour in Wales, vol. i. p. 53.

lead with the accompanying operations connected with the smelting of the ore and the separation of the metals was conducted on an extensive scale for a very long period. The tribute paid by Britain to the Roman empire consisted principally of lead.

There is no written history of this period of commercial prosperity in Great Britain, but the enormous extent of the débris left by the ancient miners justifies the belief that these operations extended over at least three centuries; it is probable, however, that mining operations were abandoned before the dismemberment of the empire.

Within the past century many pigs of ancient Roman lead have been found in England, and are preserved in the museums at London, York, and elsewhere; these pigs generally bear Roman inscriptions, sometimes referring to the mine from which the ore was procured, and usually to the period in which they were smelted, indicated by the name or the initial of the reigning Roman emperor. In 1783 a pig of lead was found in Hampshire, bearing the following inscription, NERONIS, AUG. EX. KIAN, IIII, COS. BRIT., implying that the lead was taken from the mines of the Kiangi (Welsh) in the fourth consulate of the Emperor Nero, about A. D. 60. On the reverse side was the following, — EX ARGENT., meaning "free from silver," indicating that the lead had been subjected to a metallurgical process to separate and remove the silver. Other pigs of Roman lead found in England bear the names of Britannicus, Claudius, Nero, Domitian, Hadrian, Antoninus, and Verus, reigning from A. D. 41 to 169.[1]

A writer in "Archæologia" describes at great length several pigs of Roman lead found in England, upon one of which,

[1] Hunt, British Mining, p. 25. See also The Metallurgy of Lead, by John Percy, M.D., F.R.S. (London, 1870), p. 214; Pennant, vol. i. pp. 51, 59; Archæologia, vol. vii.; John Phillips, Rivers, Mountains, and Sea Coast of Yorkshire (London, 1855), p. 71; Arch. Journal British Archæological Association, vol. xxiii.

found near an ancient smelting-place in Somersetshire, is the following inscription: LUCII, ARVCONI, VERECVDI, METALLICI, LVDDINENSIS, or, "the property of Lucius Aruconius Verecundus, lead merchant, of London." This pig of lead, although of undoubted Roman origin, bore no mark by which the date of its production could be determined. Verecundus was probably the owner or lessee of the mine, and resided in London.[1]

The products of some British mines being worked to-day, when prepared for market, are of the same shape and size, and bear inscriptions of the same general form as the products of the same mines in the time of Roman occupation.[2] A pig of lead found in Shropshire distinctly shows the grain of the wooden model from which the mould was formed,—so much so that the nature of the wood (oak) is clearly distinguished.

Early writers have little to say of the methods by which ores and minerals were exploited in ancient times, and we are obliged to supplement the meagre information handed down to us with the testimony of modern travellers and archæologists who have explored the seats of old mining enterprises, and have discovered and described ruins which are frequently the only evidences of operations of vast extent, and which attest the skill and energy of the ancient miner and metallurgist.

In remote periods, and among barbarous nations, mining operations were of the crudest character. Sharpened flints, or the teeth of wild animals fastened to a stick, were commonly used for excavating, and stone hammers and mauls sufficed to break the ore. In the stone age in Great Britain the flint for the weapons and implements of the natives was often procured from subterranean workings. Dawkins refers to two of these seats of mining enterprise, in which

[1] Archæologia, vol. vii. p. 171.
[2] Phillips, quoted by Percy, p. 214.

shafts connected by galleries had been sunk to find flint of proper character. The miners were not acquainted with the art of timbering their shafts and galleries, and consequently were unable to drift to any considerable distance underground, and when the flint within easy reach was exhausted they sunk a new shaft. In one of these old shafts many of their tools have been found, comprising picks made of the antlers of the stag, polished stone celts, chisels of bone and horn, and little cups made of chalk, which Dawkins thinks held the grease which provided light for their work.[1]

The Egyptians knew how to smelt iron and to manufacture bronze long before the date of the earliest written history; and it is probable that other nations possessed these arts at a very remote period, thus providing themselves with picks and hammers of metal. It is said that the Egyptians used bronze chisels for working the syenite of their quarries; and the stupendous character of the ruins of ancient Egypt has given rise to the suggestion that they possessed means of so treating bronze as to render it suitable for working so hard a substance as syenite; but if this was the case the art is now lost.[2] It is possible, however, that the power of the Pharaohs enabled them to command the services of innumerable slaves and captives, and thus substitute brute force for scientific methods.[3] The tools and implements found in ancient Nubian mines are of bronze. This is considered as strong evidence of their great antiquity, as iron was probably unknown.[4] Picks and hammers of iron, wedges of iron and

[1] W. Boyd Dawkins, Early Man in Britain (London, 1880), p. 276.

[2] The addition of small quantities of foreign metals has a tendency to make copper hard and brittle, and it has been suggested that the presence in the Egyptian copper of impurities, even in small quantities, would explain the successful use of copper chisels in working the hard syenite of their quarries.

[3] Wilkinson, Ancient Egyptians, vol. ii. p. 158.

[4] Heeren, Ancient Nations of Africa, vol. ii. p. 333.

of bronze have been found in ancient mines in Greece, in the Isle of Elba, in France, Spain, England, and in other European countries.[1] The picks and hammers were frequently of great size, much heavier than those in use to-day. These implements, supplemented with fire, were the means used by the ancients to bore into the mountains in search of ore.

A reference to mining is found in the book of Job: "Surely there is a vein for the silver and a place for gold where they fine it. Iron is taken out of the earth, and brass is molten out of the stone. He setteth an end to darkness, and searcheth out all perfection; the stones of darkness, and the shadow of death." "There is a path which no fowl knoweth, and which the vulture's eye hath not seen. The lion's whelps have not trodden it, nor the fierce lion passed by it. He putteth forth his hand upon the rock; he overturneth the mountains by the roots. He cutteth out rivers among the rocks; and his eye seeth every precious thing. He bindeth the floods from overflowing; and the thing that is hid bringeth he forth to light."[2]

The Egyptians did not sink shafts, but drove levels or galleries into the mountains, supporting the roofs by leaving columns of natural rock. Diodorus refers to galleries in the Spanish mines of marvellous extent.[3] Leger directs attention to the wonderful empirical knowledge of the ancient miners. Though ignorant of geological science they followed the veins or beds of ore with great exactness, and when by reason of a fault the vein was lost they invariably found it. Their exploitations, however, were conducted wherever possible on the crest of the vein; as when they were obliged to follow it far below the surface the difficulties arising from defective ventilation, the presence

[1] Leger, Les Travaux Publics, etc., p. 690.

[2] Job xxviii. 1–3; 7–11.

[3] Diodorus, vol. i. p. 321.

of water, etc., frequently occasioned the abandonment of the work.[1]

The mining by the Romans in England was generally superficial. They opened the vein on the surface, exploiting to but little depth but following it longitudinally to great distances, forming deep ditches or open cuttings. The vast extent and richness of the deposits rendered it unnecessary to follow the lode where serious obstacles intervened, and in such cases the workings were abandoned and new prospects were exploited.[2] Phillips thinks the ore near the surface was exposed by the method called "hushing." The miners in the north of England conduct this process in the following manner: A reservoir is constructed upon elevated ground, and when a large quantity of water is collected the wall of the reservoir is cut, and the water rushing down the hill with great violence tears up and removes the soil, exposing the mineral.[3]

The extensive rock excavations of the ancient miners were made possible by what has been termed in later times "fire-setting." Fires were made against the face of the rock, which, under the influence of heat, split, and pieces of rock were readily removed by inserting the point of a pick, or of a wedge into the crack. One of these wedges, almost entirely incrusted with lead ore, has been found in an ancient mine in Wales.[4] This method of removing rock was practised, not only in ancient times, but during the middle ages, and in some districts even after the introduction of gunpowder for such purposes. Agricola describes and illustrates the process of fire-setting, and shows the preparation of the wood and the methods em-

[1] Leger, Les Travaux Publics, etc., p. 690.

[2] John Williams, F.S.S.A., The Natural History of the Mineral Kingdom (Edinburgh, 2 vols., 1810), vol. i. p. 350.

[3] Hunt, British Mining, p. 505.

[4] Pennant, A Tour in Wales, vol. i. p. 74.

ployed.[1] In the ancient mining laws of England regulations for fire-setting were established, providing that the fires should not be made during the hours when miners were at work.[2] Sometimes the ancient miner poured water or vinegar upon the heated rock, to facilitate cracking and splitting, when heat alone failed to produce the desired effect.[3] Hannibal is said to have employed this method of removing rocks when building his road across the Alps. The use of fire in galleries of considerable extent must frequently have been fatal to the miners, by filling the mines with the vapors of the products of combustion. It is probable, therefore, that this means of excavating was resorted to only when the strata were composed of the hardest and most refractory materials; ordinarily the pick, hammer, and wedge were used, and heavy mauls shod with iron, and worked probably by two or more men, on the principle of the battering-ram.

The galleries were commonly of the smallest possible area, and the ore and débris were brought out in small quantities at a time. In some cases the miners were unable to stand erect or to pass each other, when the material was filled into small baskets and passed from one to another, the men forming a line from the face at which the work was being prosecuted to the mouth of the mine. Pliny describes this method of removing the ore in narrow galleries, and says, "The last man was the only one who saw the light of day."[4] This method was practised as late as 1831 in the lead mines of Ajmeer, in India. The ore was broken where it was found into small pieces and put into baskets; as the gallery was not high enough to allow the miners to stand erect they sat upon their

[1] Georgius Agricola, De Re Metallica Basileae (1556), p. 80.

[2] Hunt, British Mining, p. 144.

[3] Pliny, Natural History, book xxxiii. chap. xxvii.

[4] Pliny, Natural History, book xxxiii. chap. xxi.

haunches in a row, and passed the baskets on from one to another.[1]

The ancient shafts were usually of the smallest possible diameter; some have been found in France so narrow that they were provided with steps, or notches, cut in opposite sides, to afford a support to the hands and feet of the miners in climbing up and down; and small cavities were hollowed out at intervals to receive the lamps to illuminate the mine. The shafts were occasionally furnished with timbering to prevent the caving of the surrounding earth, as is the custom to-day, and the roofs of galleries were supported by columns and arches of the natural rock, left for this purpose during the excavation.[2]

Occasional references to the management of water are found in the works of ancient authors. The absence of proper methods for reducing this obstacle to all deep mining operations proved a serious embarrassment, and was the occasion of the abandonment of many mines, perhaps at a time when the richest ores were in sight. This fact may explain the profitable working, in modern times, of mines abandoned in early days. The mines in Spain opened and worked by Hannibal continued to be operated for centuries. One of the mines opened by him, and supposed to be in the district of Linares, is described by Pliny as follows: "The mountain is already excavated for the distance of 1,500 paces, and throughout the whole of this distance there are water-bearers standing night and day, bailing out the water in turns, regulated by the light of torches, and so forming quite a river."[3]

At the World's Exposition of 1867, in Paris, there were exhibited several articles formerly used in mining operations in Spain and Portugal by the Phoenicians and

[1] Percy, The Metallurgy of Lead, etc., p. 294.

[2] Daubrée, L'Exploitation des Mines, etc.

[3] Pliny, Natural History, book xxxiii. chap. xxi.

Romans; among them was a basket made of reeds, closely woven, covered with tar, and fixed in a wooden frame, evidently used for bailing water from the mines. Bronze hatchets, stone hammers, iron wedges, tongs, miners' lamps of earthenware, glass vessels, a leaden chaldron, and amphoræ filled with powdered mineral,[1] recovered from ancient mines, were also on exhibition.

In some cases draining-levels, or tunnels, were constructed to discharge the water. At Las Babias, in Spain, vestiges of canals, to bring water from great distances for mining or metallurgical operations, can still be traced.[1]

According to Strabo, the Turdetani used the Archimedean screw for removing water from their mines.[2] Diodorus, referring to the Spanish mines, says: "Sometimes at great depths they meet great rivers underground, but by art give a check to the violence of the current; for by cutting of trenches they divert the stream, and being sure to gain what they aim at, when they have begun they never leave off till they have finished it; and to admiration they pump out those floods of water with those instruments called Egyptian pumps, invented by Archimedes, the Syracusan, when he was in Egypt. By these, with constant pumping, they throw up the water to the mouth of the pit; for this engine is so ingeniously contrived that a vast quantity of water is strangely, with little labor, cast out."[3] According to Daubrée, the Romans erected in the San Domingo mines, in Portugal, a series of fourteen water-wheels, each six metres in diameter, to discharge water from the mine; one wheel was placed in the bottom of the pit and lifted the water to a level above, where a second wheel took it and raised it to a still higher level, where the third wheel received it, and so on until the surface was reached.[4] The

[1] See Daubrée, L'Exploitation des Mines, etc.

[2] Strabo, book iii. chap. ii.

[3] Diodorus, vol. i. p. 319.

[4] Daubrée, L'Exploitation des Mines, etc.

ancient Mexican used buckets made of hide for bailing the water from their shafts.

Lifting pumps were introduced in mining operations at an early period. Agricola, in the first half of the sixteenth century, describes elaborate systems of lifting, bucket, and chain pumps, some worked by men turning a crank attached to a gear, others worked by men operating a treadmill; in others the power is supplied by undershot or overshot water-wheels, and in others by horse-power. One of these systems consisted of a series of several pumps, the lowest raising the water to a reservoir, in which another pump was placed which raised it to a reservoir still higher, when a third raised the water to the surface. This author also describes chain-pumps arranged in a similar manner.[1]

So late as 1690 the water in the coal mines of England was reduced by chain-pumps worked by water-wheels; and in 1709 no better means was in use in the Newcastle district.[2]

The steam-engine is said to have been introduced for pumping water from mines as early as 1702, but Pryce says the Marquis of Worcester, in a work which he published in 1663, was probably the first who suggested raising great quantities of water "by the force of fire converting water into steam."[3]

In the South American silver mines the natives abandoned work when the water became troublesome; and the early miners in Missouri, and in the Galena district, frequently surrendered rich prospects for the same cause.[4] According to Pumpelly, the Japanese were very skilful in mining above the water level, and found and worked

[1] Agricola, De Re Metallica, p. 131 *et seq.*

[2] Phillips and Darlington, Records of Mining and Metallurgy, p. 27.

[3] W. Pryce, Mineralogia Cornubiensis, p. 153.

[4] Schoolcraft, A View of the Lead Mines of Missouri, etc., p. 159.

countless deposits, exhausting them down to the point where water compelled them to leave; as a consequence great numbers of veins have been abandoned at a time when they were most productive.[1] Draining by the construction of levels was frequently resorted to by the ancient miners, but when the ore could be reached by driving galleries into the mountain this method was adopted in preference to sinking shafts.

We know but little of the methods adopted by the ancients to secure proper ventilation of their mines. Pliny mentions the occurrence of "sulphureous" or "aluminous" substances in deep wells, which were fatal to those who entered them; and he recommended the sinking of vent holes on each side of the well to carry off the noxious exhalations.[2] In the sixteenth century methods of ventilation were well understood. Agricola describes several devices for supplying mines with fresh air; by pits connected with the shaft, or with the galleries, or with chimneys; or by forcing air into the shaft by huge bellows, worked by horse-power or water-wheels.[3] It is possible the ancients were acquainted with and used similar expedients for the supply of pure air to their shafts and galleries.

The ancient miners used torches of light and dry wood to enable them to carry on their work underground; in some cases, it is said, the duration of these torches served to mark the task required of the miner.[4] The ancient Egyptians at first used torches, but in the time of Agatharchides they used lamps fastened to their foreheads to light them at their work.[5]

[1] R. Pumpelly, Across America and Asia, p. 145.
[2] Pliny, book xxxi. chap. xxix.
[3] Agricola, De Re Metallica, p. 159.
[4] Pliny, book xxxiii. chap. xxi.
[5] Diodorus, vol. i. p. 158.

In ancient times work in the mines was considered an inferior employment, fit only to be performed by captives and slaves.

In remote times all captives taken in war were put to death. One of the first steps in civilization consisted in sparing the lives of such captives and enslaving them. The carvings on the Egyptian monuments bear frequent reference to the enslaving of captives, and in that remote period traffic in slaves was recognized as a legitimate pursuit, to be conducted by States, princes, or by private individuals. The workers in the Egyptian mines were principally captives taken in war, notorious criminals, and other offenders. The fate of these wretched beings was pitiable in the extreme. They were forced to work in chains, under the supervision of overseers who were ignorant of their language and whom they could not understand; neither age nor sex was spared; the sick and the maimed, men, women, and children, were driven to their work with imprecations and blows.[1]

The mines in Macedonia were at one period the property of the community, and were leased to private individuals who were owners of great numbers of slaves; these slaves were under the supervision of overseers, who frequently were slaves themselves. Slavery as it existed in Greece at this time does not present such a terrible aspect as in the days of ancient Egypt. The principal slaves — those to whom was intrusted the care of the cattle, and other responsibilities — had the entire confidence of their masters, were well treated, and had slaves under them. The custom of that time, of making slaves of those taken in war or in

[1] Agatharchides, De Rubro Mari; Geographiæ Veteris Scriptores, etc., edited by John Hudson (Oxon. 1698). According to Heeren, great quantities of human bones have been discovered in the galleries of the Nubian mines, — the remains of the poor wretches who were buried and smothered by the caving walls.

the freebooting expeditions of the inhabitants of the countries bordering upon the Mediterranean, rendered any man liable to become a slave, and frequently the slave was as well born as his master.[1] Slavery as it existed in Rome, under the Commonwealth, was also of this character. Business of all kinds was conducted by slaves; bankers intrusted their affairs to them, and the business of building, architecture, mining, and manufactures of all kinds, was conducted by slaves.[2]

When the Romans had conquered Spain they found that the Carthaginians had depended upon slave labor for working the mines; they accordingly continued the practice, and soon the demand for this class of labor increased to such an extent that great expeditions were fitted out for the express purpose of taking captives. Diodorus relates that after Iberia came into the possession of the Romans, "the mines were managed by a great throng of Italians, whose covetousness loaded them with riches; for they bought a great number of slaves, who were delivered over to the overseers of the mines."[3] Renault, in his voyage, in 1719, from France to the mining region in Missouri, stopped at San Domingo and purchased five hundred slaves to work his mines.

The Romans sometimes procured men to work their mines in Spain by conscription. The people who lived in the neighborhood of the mines were compelled to give their own services as well as that of their families. This oppression, however, drove them to escape, until a law was enacted by which all the children were required to give their services, and those who had left were ordered to return.[4] Conscription has been resorted to in later times to procure

[1] Grote, History of Greece, vol. ii. p. 133.

[2] Theodore Mommsen, History of Rome, translated by W. P. Dickson, D.D. (New York, 1872), vol. ii. p. 450.

[3] Diodorus, vol. i. p. 320. [4] Jacob, History of Precious Metals, vol. i. p. 173.

miners. In 1296 a large number of men were impressed in Wales and Derbyshire to work the mines of Devon; and in 1360 a writ was issued authorizing certain persons to take up as many workmen as was necessary to work the King's mines in Devon, allowing them reasonable wages, and to arrest and imprison such as should resist.[1]

It has always been understood that captives taken in war were bound to undertake any tasks set by their captors; and we find that not only in Egypt, Greece, and Rome, but in later times, the practice has been continued. Galgacus, a British leader, in his address to his troops before engaging in battle with the Romans, warns them of their fate should they be overcome, and tells them that slavery and work in the mines will be the penalties of defeat.[2] On the 30th of October, 1777, the Congress of the United States directed the Board of War to write to the Government of the State of New York recommending it forthwith to take measures to have the lead mines in that State worked, and promising, in case laborers were scarce, to supply prisoners-of-war for that purpose.[3]

From the earliest historical period those convicted of crimes against the State have been condemned to work in mines. This custom prevailed in Egypt, Greece, and Rome, and has been general until very recent times. In a petition to Charles I., in 1641, Mr. Bushell prays for an extension of his lease, and for the employment of convicts to work his mines.[4] The hardships of Russian state-prisoners in the mines of Siberia is a never-failing theme for story, and a recent issue of a St. Louis journal contains an account of the sufferings of the convicts employed in the coal mines of Kentucky. The galleries are said to be but four feet

[1] Hunt, British Mining, p. 130.
[2] Tacitus, Life of Agricola, quoted by Hunt, p. 24.
[3] Journal of Congress, vol. iii. p. 365.
[4] Phillips and Darlington, Records of Mining, etc., p. 20.

high, so that the men are obliged to assume a kneeling position while working; the food is insufficient, the sick and maimed are not excused from labor, and the lash is sure to follow failure to accomplish the task within the allotted time.[1] In the mines of Alabama the convicts who attempt escape are pursued by bloodhounds.[2] The employment of convicts in the mines in the United States is not confined to the States of Kentucky and Alabama; other Southern States lease the labor of their convicts to contractors who employ them in a similar manner.

At the date of the establishment of the Empire the Romans had secured the possession of the mineral treasures of the known world, — the mines of Sicily, Sardinia, and of Spain, of Asia Minor, and of Greece, the mineral wealth of Great Britain and of Gaul, and the treasures of Northern Asia and Africa.[3]

At the period of these conquests the Romans had given little attention to the peaceful arts, and were unskilled in mining and metallurgy. The power of their arms had given them great mineral wealth, but they were obliged to turn to the inhabitants of the conquered countries for the knowledge and skill necessary to utilize their new acquisitions; they posted their legions at strategic points along the highways of the conquered provinces, established fortified camps near the mines, and received the product of the industry of the subjugated people and transported it to Rome.

At the origin of the republic the mines were free. The proprietor of the land was owner of all minerals found upon it or below its surface. Under the emperors the State claimed in some cases ownership of all minerals, and in other instances mines were worked for the State. Mines

[1] St. Louis Republican, January 17, 1886.
[2] St. Louis Post Despatch, March 26, 1886.
[3] Jacob, the Precious Metals, vol. i. p. 134.

in all conquered countries were the property of the State,[1] and were worked for the emperors, slaves and captives being employed. This method proving unprofitable the system of leasing was adopted; this also was unsatisfactory, because the lessees left the poorer ores to accumulate in great heaps as rubbish, working only the purer and richer. They neglected to properly support the walls and roofs of their shafts and galleries, and when, by this neglect and the accumulation of débris, the working became unprofitable they abandoned their leases. The mines were finally taken from the lessees and worked solely for the State; they were cleaned, new and substantial improvements erected, and for a time the new system was successful. Some of the more valuable mines were guarded with jealous care; they were closed by a door, the key of which was in the possession of the governor; others were strongly fortified, and the entrance surrounded by a strong wall.[2] New mines were opened, and those already operated were worked with greater vigor; but the Romans were ignorant of scientific methods, and were dependent upon others for the skill necessary to successful mining and metallurgical operations. This fact, together with the disturbed condition of some districts, owing to the incursions of the barbarians, soon interrupted the work, and from the third century mining in the Western Roman provinces began rapidly to decline. The Byzantines surrendered their mines to the Arabs, retaining those in Asia Minor, Thrace, and Greece to the last; finally, in the fifth century, mining and kindred industries of the civilized world were almost entirely destroyed.[3]

Towards the close of the fifth century the Vandals had conquered Africa; Spain and Gaul were in the possession of the Suevi and Visigoths; the Burgundians and other

[1] Leger, Les Travaux Publics, p. 687. [2] Id. p. 689.
[3] Jacob, The Precious Metals, p. 136 *et seq.*

nations had taken Germany and other European provinces. For centuries after this time mining, manufactures, trade, and commerce, which were almost extinguished by the fall of Rome, showed little signs of revival. The rise of Mahomet and the conquest of Asia and parts of Europe by the Saracens, together with the threatened domination of these religious fanatics over all Christendom, completed the paralysis which had seized upon the arts, sciences, commerce, and progress of every kind. During this period, Hallam asserts, there appears in the secular world no vestige of manufacturing industry except of the simplest kind, and to supply the wants of the immediate community; the rich kept in their own employ workmen to furnish the necessities of a rude civilization; the clothing of kings was made by their own servants; the insecurity of property, the robbery and extortion practised upon the highways, prohibited trade and commerce except with the nearest and friendly neighbors.[1] The robber-baron in his stronghold, perched high upon inaccessible rocks, commanding an extensive view of the passes of the country, had a pack of freebooters at his back, ever ready to sally forth and swoop down upon any unlucky merchant or traveller who might be making his way through the district, and who would esteem himself fortunate to escape with the loss of his wares.

But little intercourse existed between the Eastern Mediterranean countries. Venice, however, founded by fugitives from the northern barbarians in the fifth century, had attained some prominence in the seventh, and later had some trade with the East. The Venetians were daring navigators and enterprising traders, and in the ninth century their trade attained considerable development. They had established themselves in Egypt and at ports in the

[1] Henry Hallam, LL.D., F.R.A.S., View of the State of Europe during the Middle Ages (New York, 1863, 3 vols.), vol. iii. p. 297.

Levant, and monopolized the commerce, limited except in slaves, which existed between the Mediterranean countries and the East. Their position on the sea, near the mouths of the Po and the Adige, enabled them to communicate with parts of France, Germany, and Switzerland, exchanging the products of those countries for the spices, silks, dyes, and drugs of the Orient.[1] With this meagre exception, commerce and the peaceful arts had ceased to exist, or remained hidden beneath the heavy pall of ignorance and barbarism which fell upon the civilized world, only to be lifted at the great revival some centuries later.

[1] W. Heyd, Histoire du Commerce du Levant au Moyen Age, Édition Française, par Furcy Raynaud (Leipzig, 1885), vol. i. p. 110.

CHAPTER III.

THE LEAD MINES OF THE MIDDLE AGES.

THE Saracens, after conquering Africa and Asia, turned their attention to Europe; they subjugated the islands of the Grecian Archipelago, captured Sicily, and early in the eighth century they invaded Spain. Within three years they had complete possession of the country, except a portion of the northern mountainous region, where a remnant of the Visigoths made a stand and could not be dislodged. They and their successors waged war for more than seven hundred years against their Oriental foes.

There is no existing account of the mining operations of the nations who occupied Spain immediately after the Romans. The barbarians who overran the country were a rude and warlike people, who probably contented themselves with the plunder they acquired in war.

We are also unfortunately without contemporaneous data respecting the mining operations of the Saracens in Spain. Such works of Moorish authors, of the period of occupation of Spanish territory, as are accessible rarely refer to mines, or to mining operations. If any information of this nature exists it is buried in the Arabian manuscripts in the "Escurial," — a name, curiously enough, derived from the Spanish word "escoria," meaning *dross* or *refuse,* and applied to old and abandoned mines. Modern travellers, however, have discovered vestiges of extensive mining operations which were conducted by the Moors.

Their chief mines were in the district of Linares, where some of the hills are said to have been "pierced as full of holes as a sieve;" more than five thousand galleries, within five paces of each other, have been traced, which must have yielded great quantities of silver, copper, and lead.

Some writers assert that certain of the tribes that overturned the Roman Empire settled in Bohemia, Moravia, and Saxony in the seventh century, taking with them the art of mining and of extracting metals from their ores. The first book on mining laws, written in Italy in the thirteenth century, contains numerous German technical terms and phrases, indicating that Germany was at that time one of the principal centres of mining and of metallurgical operations.[1]

It is believed that mines were opened and extensively worked in Hungary and Austria by the Romans; but there are no records extant by which this fact can be established. Extensive workings of a very remote period have been discovered in those countries, in which galleries of enormous length and shafts of great depth have been explored; and as these huge excavations were made before the use of gunpowder for mining purposes, they must have been the work of thousands of slaves, extending over many centuries, using the old method of fire-setting, or laboriously making their way through the rock with hammer, pick, wedge, and maul. In these ancient mines the purer and richer ores only were worked. The art of metallurgy had not at that time attained the perfection necessary to utilize the poorer ores.

The mines of Kremnitz and Chemnitz were worked at an early period by companies, who were successively compelled to abandon them on account of wars, pestilence, and famine.[2] The earliest records of these mines show that

[1] See Karsten, System der Metallurgie, etc.

[2] Jacob, The Precious Metals, vol. i. p. 240.

King Stephen, in the eleventh century, appointed governors of Kremnitz; and in 1241 King Bela IV. issued the first decree treating of mining privileges. In 1356 the Emperor Charles IV. gave exclusive privileges of working mines to princes and sovereigns of his empire. Regular management and working of these mines, however, has prevailed only since the sixteenth century.

The lead mines of Saxony and the Harz were discovered as early as the tenth century, but the disturbed condition of the country caused the working of them to be interrupted and desultory until the fifteenth century. The mines in Silesia were flourishing in the thirteenth century, and furnish evidence of very extensive exploitation. After a period of suspension they were again opened in 1524.

The Saxons and Danes worked the lead mines in England after the abandonment of the country by the Romans.[1] A mine at Castleton has been known for centuries as the Odin mine, and Williams thinks it was so named in honor of one of their gods.[2] Lead was mined at Wirksworth by the Saxons before 714. When Guthloc, the patron saint of the great Abbey of Croyland, in Lincolnshire, died, Eadburga, the abbess, sent a leaden coffin in which to bury him. In 835 the Abbess of Croyland granted to Humbert, the alderman, the estate of Wirksworth at an annual rental of lead, to the value of three hundred shillings, for the use of Christ Church, Canterbury. The lead mines of "Werchesrorde" are mentioned in "Domesday Book," and it is probable the town took its modern name, Wirksworth, from the lead works established there.[3]

In the time of Edward the Confessor the three manors

[1] Macpherson quotes Raynal's statement that the Saxons carried tin and lead to France in the seventh century, and sold these productions at the fairs established by Dagobert. D. MACPHERSON: Annals of Commerce, etc. (4 vols., London, 1805), vol. i. p. 288.

[2] Williams, The Natural History of the Mineral Kingdom, vol. ii. p. 447.

[3] Archæologia, vol. v. pp. 372–374.

of Bakewell, Ashford, and Hope, paid, as part of their tribute, "V plaustratus plumbi de L tabulis," or five cart-loads, or fodders, of ten pigs or blocks of lead each.[1]

From the landing of William the Conqueror the crown assumed the entire right to all mines and minerals; but the laws and regulations respecting them were of such a nature that all mining, except for iron, was discouraged. The lead mines at Werchesrorde were referred to in "Domesday Book" as the property of the crown; and those of Derbyshire were called the "King's field." From the reign of Edward I. to Henry VII. grants were made to the nobles and others to search for ores, but the grants always contained provisions by which a part of the metal produced was to be paid to the church, and another portion to the exchequer. The owner of the mine had no right to any portion of the ore found upon his estate until 1426, when he was allowed to share with the church and the crown.[2]

Several mines were worked in Derbyshire in the time of the Conqueror, and in the twelfth century lead in considerable quantities was exported to many parts of Europe, where it was used to cover the roofs of churches, castles, and other great buildings.[3] In 1233 the mines of Alderton had royal protection. The Earl of Buchan obtained a license, in 1274, from Edward I. to mine for lead in the Isle of Man. The mines in Devon were very productive in the reigns of Edward I. and II.; and in 1296 miners were impressed in Wales and Derbyshire to work them. In 1283 the burgesses of Flint, in Wales, received from the King a grant of timber out of the neighboring forests "to smelt their lead ore."[4] The lead mines of Alderton were worked in the time of Edward III., who seems to have

[1] Archæologia, vol. v. p. 372.
[2] Pennant, A Tour in Wales, vol. i. p. 77.
[3] D. Macpherson, Annals of Commerce, vol. i. p. 345.
[4] Pennant, A Tour in Wales, vol. i. p. 46.

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[4] Pennant, A Tour in Wales, vol. i. p. 46.

encouraged mining enterprises, and the silver extracted from the argentiferous lead ores "was coined within the manor." The mines of Devon and Cornwall at this time yielded large revenues to Edward the Black Prince.

During the succeeding reigns mining seems to have been neglected, for in 1488 the miners of Devon petitioned the crown for permission to work the ores discovered by them. Their prayer was granted, and soon after one thousand men were employed in the mines at Combe Martin and Beereferris. These mines were very productive for some years, and lead sold at £4 per ton.[1]

Lead occurs in many parts of Ireland, and vestiges of ancient mining have been discovered in many places. In opening the mines at Milltown, in the last century, ancient galleries were struck in which old oaken shovels and iron picks of extraordinary size were discovered, bearing all the evidences of a great antiquity.[2]

The lead ores of Ireland are all argentiferous, but the veins are generally thin and the ore insufficient in quantity to make mining profitable, except when the metal commands a comparatively high price.

Mining was abandoned in France from the fourth century until the time of Charlemagne, who issued an edict granting mining privileges to his sons. During this period France depended upon Spain and Great Britain for her supplies of lead. Pigeonneau mentions the importation of lead in the sixth and seventh centuries. The exploitation of argentiferous lead mines was conducted with some vigor during the reign of Charlemagne, but after his death it gradually declined, and was soon abandoned. Money was coined at Ardèche, and in Melle, in the ninth century, and vestiges of ancient works have been discovered at other places which are attributed to this period. In 975 the Bishop of Toul reserved to himself the tithes of the silver

[1] Hunt, British Mining, p. 129. [2] Id. p. 166.

mines in a grant to the church of Diez. The mines in the department of Aveyron are said to have been reopened in the tenth century and worked by miners brought from foreign countries. In 997 and 1120 grants were made to mine for silver, showing that mining operations were prosecuted at that period. According to Leger a revival of mining in France took place in the eleventh and twelfth centuries in sympathy with the general rise of material progress throughout the world. Mining companies were formed, and many works undertaken in the Vosges and Pyrenees, in Béarn, Auvergne, and in other districts, but during the fourteenth century mining operations were generally suspended, owing to the wars and to the exorbitant demands of the great nobles, owners of the land, — who claimed ten and frequently twenty per cent of the production as rent, — and to the want of proper appliances for providing ventilation, and for reducing the water in the mines.[1]

The mines of L'Argentière, in the Alps, worked by the Romans, are said to have been reopened in the twelfth century. In the thirteenth century France produced articles of prime necessity and of common use, but the raw materials were generally procured from abroad. English vessels brought to Bayonne and Bordeaux herrings, tin, and lead. Rouen had in the previous century a monopoly of the wine trade, exchanging this commodity with the English for lead and copper. In the thirteenth century the argentiferous lead deposits in Dauphiné, Vivarais, Savoy, Auvergne, and in the Pyrenees, were worked to a limited extent.

In the fifteenth century Louis XI. encouraged mining by the issue of several orders, by the provisions of which a Master-General of Mines was appointed, whose powers extended over all mines in the kingdom. Those who had

[1] See Leger, Les Travaux Publics, etc., p. 775; also Daubrée, Aperçu Historique, etc.

mineral deposits on their property were ordered to publicly declare it, and to take steps to exploit them. The King abandoned his right to the royal tenth for twelve years, and ordered this moiety divided between the Master-General and the owner of the mine, or the chief miner.[1] The exhausted condition of France, however, together with the unpopularity of the superstitious and base-hearted monarch, prevented any considerable exploitation of the mines during his reign.

Malus states that from the time of Charlemagne to that of Gaston de Foix (1500) there was little or no mining in the Pyrenees, owing to the vicissitudes of the times, especially severe upon the frontier.[2] Gaston de Foix, Duc de Nemours, brother of Charles of Navarre, is said to have worked these mines to such advantage as to enable him to surpass all the monarchs of his time in his expenditures.[3]

The ancient mines at Sala, in Sweden, are known to have been worked as early as 1280.

Lead and silver mining was prosecuted in the Italian Alps in the middle ages with considerable vigor. Piedmont and Modena are rich in minerals, while the mountains in Tuscany are traversed by veins of argentiferous lead ores. Most of these localities were the scene of extensive exploitation in the middle ages, and the numerous remains in the neighborhood of the ruins of the Etruscan city of Luna — so named on account of the occurrence of silver ores there — attest the enterprise of its inhabitants. The mines in the central and southern districts of Tuscany were worked in the middle ages, and are thought to have been known to the Etruscans. The modern explorer may count hundreds of ancient pits and ruins of furnaces in

[1] See H. Pigeonneau, Histoire du Commerce de la France (Paris, 1885), première part, pp. 73, 421.

[2] Sieur de Malus in The Art of Metals, by A. Barba.

[3] Jacob, The Precious Metals, vol. i. p. 263.

the neighborhood of the Massa Maritima, where many lead mines were worked during this period.

Soon after the expulsion of the Arabs from Sardinia by the Pisans, in the eleventh century, the argentiferous lead mines were reopened and extensively worked. Shafts were sunk through the hard rock to the depth of six hundred feet by fire-setting, and great heaps of slag and scoriæ attest the magnitude of the work. In 1323 the island fell into the hands of Spain, and mining industries were neglected.[1]

In the fourteenth century, if we accept the statements of Sanuto, quoted by Macpherson, the Egyptians imported large quantities of the precious and baser metals which were needed for their trade with the natives of Ethiopia. These commodities were supplied by the galleys of the Italians, who commanded the trade of the Mediterranean.[2]

The period from the fall of Rome to the beginning of the fifteenth century offers but little of interest respecting mining and metallurgy. The ignorance and barbarous superstition which prevailed during the early part of the middle ages yielded but slowly to the revival, which began with the crusades in the eleventh century. The rise of the Italian cities was followed by the increase in commercial importance of Germany, Holland, and of England; and the civilized world was finally ready for the next great event which was to mark an epoch in its commercial history. The discovery of the continent of America by Columbus, sailing under the flag of Spain, infused a spirit of adventure and discovery into other European nations whose inhabitants depended for their sustenance partly upon maritime pursuits, while the enormous booty secured by the conquerors of Mexico and Peru roused the cupidity

[1] C. J. B. Karsten, System der Metallurgie, Berlin, 1831.
[2] Macpherson, Annals of Commerce, vol. i. p. 491.

of the civilized world; and when the aboriginal inhabitants of conquered America had been despoiled of their treasures, and no more worlds were left to conquer, the adventurers turned to the original source of supply, and a period of great mining activity ensued.

CHAPTER IV.

LEAD MINING IN EUROPE, ASIA, AFRICA, AND AUSTRALIA IN MODERN TIMES.

IN the early part of the reign of Elizabeth, encouraged by the liberal policy of that wise sovereign, interest in mining operations in England was revived, and grants in great numbers were issued to sink shafts and to search for ores. Before this period England for many years had depended almost entirely upon foreign nations, especially Germany, for all articles of iron, brass, and copper, even those of the simplest character and in most common use. Mining had been generally abandoned, and the art of working in metals was almost entirely lost. Elizabeth, however, in order to recover the lost ground, invited to her dominions miners, smelters, and artisans, and absolutely prohibited the importation of metallic article. Attempts had been made in previous reigns to encourage mining and metallurgical industries. In 1452 King Henry granted safe conduct for four years to three skilled miners and thirty other persons from Bohemia, Austria, and Hungary, to be employed in his mines. At this period the mines in these countries had been worked for centuries, and their miners were esteemed the most skilled in Europe. In 1484 the importation of many articles of foreign manufacture was prohibited for a term of years.[1] These expedients had

[1] Macpherson, Annals of Commerce, vol. i. pp. 669, 706.

failed to establish the manufacture of metallic articles in the kingdom; but Elizabeth followed up the concessions above mentioned; she founded the "Society of Mines Royall" and the "Society for the Minerals and Battery Work," and by making liberal grants she encouraged the revival of the metal-working industry. Her vigorous policy soon bore fruit, and in a short time the manufacture of metallic wares was completely established in her dominions, and her artisans were enabled to supply her people with goods of domestic manufacture.[1] The value of lead in England at this time was about £8 per ton. In the Court Records of the East India Company, under date Dec. 10, 1600, among the items of expense of fitting out the first squadron sent to the East Indies appear the following: "Order is geaven to the said M^{r} Ald^{r} Bannyng to pay to W^{m} Waithall 224^{li} 2^{s} 0 for 29 fodder 4^{c} 1^{qr} 16^{lb} of Peate Lead bought at vij li xiij$^{s.}$ iiij^{d} the ffodder."[2]

Among the Germans brought over by Elizabeth was a smelter named Houghsetter, who settled in Cardiganshire, and exploited the lead mines of that district for some years. His operations proving disastrous he abandoned them, but his mines were afterwards worked deeper, and proved very profitable. So much silver was recovered from the argentiferous lead ores that Mr. Thomas Bushell, who worked them, established a mint in the neighborhood, and it is said was enabled to clothe the army of Charles I. out of a portion of his profits.[3] A writer visiting the mines in 1670 says he inspected the ore-house, the old mint, the stamping and refining mills, and the red lead mills.[4]

There are no trustworthy accounts of the production of lead in England previous to 1845, except the output of the

[1] Pennant, A Tour in Wales, vol. i. p. 80.

[2] Henry Stevens, The Dawn of British Trade in the East Indies (London, 1886), p. 95.

[3] Hunt, British Mining, p. 153.

[4] Ibid., p. 154.

mines at Alston-Moor, which were granted to Greenwich Hospital in 1734. The records of these mines have been preserved since 1768. The statements of contemporaneous writers respecting the output of lead generally refer only to certain mines or districts. Lead was an important production and article of commerce in the sixteenth and seventeenth centuries. In 1611 an impost of twenty shillings per ton was laid upon lead as being one of the three staple commodities of the kingdom.[1] Sir Josiah Child in his "Discourses on Trade" says: "Our lead and tin, which are natives, and by God's blessing inseparably annexed to this kingdom, carry on much of our trade to Turkey, Italy, Spain, and Portugal, besides great quantities that are sold to Holland, France, and to the Indies." According to Pennant, the Llangynog lead mines, discovered in 1692, yielded four thousand tons annually for forty years. Lead sold at this time at £7 per ton.[2] In 1708 there were seventeen smelting furnaces and eight refining furnaces in Cardiganshire and Glamorganshire; and in 1703 the Mines Royall Company ordered that "all refining processes be kept secret."[3] In 1765 lead to the amount of one thousand five hundred to two thousand tons was exported from the Frith of Forth to Holland, and one thousand tons from Newcastle and other ports. In this year lead sold at £14 to £15 per ton.[4] Bishop Watson estimates the production of lead in Derbyshire at the date of the publication of the third volume of his "Chemical Essays" (1780) at seven thousand five hundred tons, and

[1] See Analytical Index to the Series of Records known as "The Remembrancer," preserved among the archives of the City of London. Privately printed for the City of London, 1878. According to Macpherson, this impost duty on lead, tin, wool, etc., amounted in 1613 to £10,000. Annals of Commerce, vol. ii. p. 274.

[2] Pennant, A Tour in Wales, vol. ii. p. 347.

[3] Col. Grant-Francis, Smelting in Swansea District, etc. (London, 1881), pp. 84, 91.

[4] Macpherson, Annals of Commerce, vol. ii. p. 345.

says that "fifty years ago" (1730) the annual production reached ten thousand tons. He was unable to find any trustworthy records of the quantity annually smelted in Great Britain, but estimated it at thirty thousand tons.[1] Referring to the trade of Chester, then an important shipping port for the lead mines of Wales, Pennant states that the exports in 1771 amounted to four thousand five hundred tons of lead and seven hundred tons of lead ore. On account of the American war, in 1776 this trade had fallen to four thousand tons of lead and six hundred tons of ore. From 1758 to 1777—nineteen years—there was entered at the custom house at Chester seventy-nine thousand five hundred and thirty-three tons of lead, twelve thousand eight hundred and forty tons of lead ore, and two thousand seven hundred and sixty-seven tons of litharge. This did not simply represent the product of the Welsh mines, since a quantity of lead ore was brought in from Scotland.[2] There were six refining establishments in this district at that time.

Lamborn says that in 1810 Great Britain produced twelve thousand five hundred tons of lead, which amount exceeded the production of all the rest of Europe.[3]

The general introduction of improved methods of mining, early in this century, rendered it possible to reopen old mines, abandoned on account of flooding, and to work them deeper, besides reducing the cost; consequently the output rapidly increased until 1845, when the production of Great Britain exceeded forty-six thousand tons.

The mines in Cornwall were worked in ancient times; but in the eighteenth century their output was insignificant, and even as late as 1835 the total production of this

[1] R. Watson, D.D., F.R.S., Chemical Essays (5th edition, London, 1789, 5 vols.), vol. iii. p. 316.

[2] Pennant, A Tour in Wales, vol. i. p. 203.

[3] R. H. Lamborn, Ph. D., The Metallurgy of Silver and Lead, p. 23.

county is placed at less than two hundred tons; but in the period extending from 1845 to 1851 the output reached ten thousand tons annually, gradually declining however to five thousand tons in 1864, and to less than one thousand in 1879.

The increase in the output of Great Britain continued until 1856, which seems to have been the culminating period of her prosperity in this industry, when the production reached seventy-three thousand tons. The output ranged from sixty-three to seventy-three thousand tons until 1873, when it fell to fifty-four thousand. At this time the extraordinary increase in the production in the United States began to be felt; besides, Spain and Germany increased their productions, and the price of lead gradually but steadily declined. The cost of mining increases as the upper deposits are exhausted; so that in later years, notwithstanding the adoption of improved methods in mining, it is probable that but little reduction has been made in England in the cost of ore when delivered at the pit's mouth; besides, the amount of silver in the British lead ores has steadily decreased since 1871.[1] The fluctuations in the price of lead have been somewhat remarkable. Between 1800 and 1810 the average price per ton in London was £27 14s. 6d.; from 1811 to 1821, £23 6s. 6d.; from 1822 to 1832, £20 7s. In 1832 it fell as low as £13 10s., and in 1858 the average price was £21 10s. In 1873 the market price was £23 6s., but it steadily declined to £10 5s. 8d. in March, 1885, which is the lowest price at which lead has been sold for many years. It did not long remain at this extreme low value, but advanced, until in March, 1886, it had reached £13 6s. This enormous decline in value had its effect upon the mining interests of Great Britain. Hundreds of lead mines have been closed, resulting in great distress among the miners. Sir Theodore

[1] Hunt, British Mining, p. 836.

Martin, speaking at a meeting of lead miners in Wales, held in support of the conservative candidate at the election in 1885, said that one hundred and forty-nine lead mines in Great Britain were closed, and forty thousand miners thrown out of employment on account of the competition of Spanish lead, the Spanish miners working for 1s. 2d. per day. English lead ore, which sold for £14 12s. 6d. per ton in 1877, had fallen to £7 3s. 6d. The speaker insisted that something should be done to protect English workmen. The entire output of Great Britain fell to forty-three thousand four hundred and nineteen tons in 1883, to forty thousand and seventy-five tons in 1885, and to thirty-seven thousand six hundred and eighty-seven tons in 1886.

Large quantities of ore and argentiferous lead are annually imported into Great Britain, principally from Spain. In 1872 these imports amounted to nearly seventy thousand tons, increasing to one hundred thousand tons and over in 1879. The export of lead is large, amounting to over forty thousand tons in 1881. The home consumption in Great Britain has ranged from eighty-six thousand tons in 1872 to about one hundred thousand tons in 1881.

The argentiferous lead of Spain was formerly desilverized in Great Britain; but the art of refining has lately been fostered by the Spanish Government, and English smelters have lost much of the business. Hunt makes an interesting estimate of the total production of lead in Great Britain from the earliest period. Assuming the mean annual output of the lead mines at three thousand tons the total quantity raised amounts to more than seven million tons.[1]

Lead is found in the Australian colonies of Great Britain, and has been produced in limited yet increasing quantities

[1] See Hunt's British Mining for elaborate statistics and tables, showing production of the lead districts, prices, etc., in Great Britain.

for twenty years or more. Percy mentions having seen in 1859 a quantity at the smelting-works in Flintshire. During that year several hundred tons were imported.[1] The product of the Australian colonies steadily increased until 1884, when seven thousand one hundred and seventy-nine tons were brought to the British smelters.

A letter from New South Wales to the editor of the "Engineering and Mining Journal," dated Sept. 30, 1886, tells of the discovery of an immense carbonate deposit at Broken Hill, which is three hundred and forty miles from Adelaide and eight hundred from Sydney. The ore is said to yield one hundred ounces of silver to the ton and twenty-six per cent of lead. The extent of the deposit may be appreciated perhaps from the statement of the correspondent of the "Journal," who seems to be considered trustworthy by the editor, and who estimates that they have *in sight* sixty million ounces of silver, and two hundred and sixty thousand tons of lead. Unfortunately the mines are remote from the seaboard, but efforts are being made to extend a railway, now in process of construction, upon the completion of which this vast deposit of lead will compete in the markets of Europe with the produce of German, Spanish, and British mines.[2]

The wonderful discoveries in America, and the success of the expeditions of Pizarro and Cortez so occupied the attention of the Spaniards, after the expulsion of the Moors from Spain, that little mining was prosecuted in their own

[1] Percy, The Metallurgy of Lead, p. 430.

[2] The Australians have lately become thoroughly aroused to the importance of their deposits of argentiferous lead ores, and to the necessity of reducing the ores, and of refining and manufacturing the product in their own dominions,—thus saving the cost of carriage of the ores and bullion to England, and of the return of the manufactured product. A late issue of one of our mining journals contains the important statement that The Australian Smelting and Refining Company has been organized at Melbourne, and that furnaces and refining works will be at once established upon an extensive scale.—Engineering and Mining Journal, New York, May 28, 1887.

country. In 1571 the old Carthaginian silver-lead mine at Guadalcanal, on the borders of Seville and Cordova, was reopened, and exploited for some years, but soon abandoned. Two Germans, named Fugger, obtained a lease of some mines of silver and cinnabar, and succeeded in accumulating considerable wealth, which they safely conveyed to their own country. In 1690 a Jew, Gomez, made an unsuccessful mining venture; and in 1728 an Englishwoman of rank, Lady Herbert, undertook mining operations on a large scale, but met with disaster. A French company, in 1768, succeeded in dissipating a large capital in a fruitless endeavor to drain some old mines.

For many years but little mining was done in Spain, but in 1825 a decree was passed opening the Spanish mines to native and foreign competition, and in a short time no less than three thousand mines, Lamborn tells us, were opened in one district; and the production of lead increased to so great an extent as to cause a depression in the price, resulting in the suspension of operations at many of the poorer mines of Germany and of England. The production of lead in the mines of the Sierra de Gador Lujar reached forty-two thousand tons in 1827. The price of the metal was reduced so much that mining was no longer profitable, and in order to raise the price to a remunerative point, the miners were obliged to reduce their work to half time. The superficial deposits were gradually exhausted, and the production rapidly decreased, until 1839, when the deposits in the Sierra de Almagrera were discovered. Another period of excitement and increase of production followed, resulting in the opening of more than eight hundred mines, and the establishment of thirty-eight smelting-works in the district, producing, in 1845, more than eight thousand tons of lead. These deposits soon showed signs of exhaustion, and rapidly declined in importance; when the ancient mines in the district of Linares were reopened

by English capitalists, and, by improved methods of mining, this has been made one of the most important lead producing districts in the world. A most extraordinary development in lead mining occurred in the province of Murcia in 1857, if we are to accept the statement of Consul Williams, who says that one thousand two hundred mines were exploited in that year. In Almeria two hundred mines were worked in 1860. Mining for lead is also extensively conducted in Teruel, Belmonte, La Selva, and the Cantabrian provinces. Percy places the production of lead in Spain in 1866 at sixty-six thousand eight hundred and three tons. According to the Report of the United States Geological Survey, the export of lead from Spain, including ore and base bullion reduced to lead, in 1878 amounted to ninety thousand eight hundred and forty-two tons, rising to one hundred and thirty-five thousand six hundred and ninety-one tons in 1883, but declining to one hundred and nine thousand and fourteen tons in 1885. To these amounts the domestic consumption must be added to arrive at the total output. These statistics are not altogether trustworthy; but Spain at the present time probably stands second in the list of the lead producing countries of the world, — and possibly the first, her only rival being the United States, whose output this year may be less than the production of Spain.[1]

Ancient Lusitania has produced an insignificant amount of lead in modern times. Consul Williams estimates the production of Portugal in 1857 at no more than six hundred tons.[2]

[1] See Lamborn, The Metallurgy of Silver and Lead, pp. 20, 21; Percy, The Metallurgy of Lead, pp. 247, 499; Jacob, The Precious Metals, vol. i. p. 280; Albert Williams, Jr., Mineral Resources of the United States (Washington, 1886), p. 266; J. D. Whitney, The Metallic Wealth of the United States (Philadelphia, 1854), p. 377; United States Consular Report, No. 75 (Washington, 1887); Report of Consul Williams, p. 568.

[2] United States Consular Report, No. 75 (Washington, 1887); Report of Consul Williams, p. 570.

Germany is now the second country in Europe in the production of lead. Her mines in Saxony, Silesia, and in the Harz were reopened in the fifteenth and sixteenth centuries, and have been exploited with little intermission ever since. Reference has been made to the fostering care exercised by that nation over the arts of mining and metallurgy, and the superiority of German methods was evidenced as early as the sixteenth century by the introduction of German miners and workers of metal into England by Elizabeth, and into France to work the abandoned mines of those countries. There appeared in the sixteenth century the exhaustive and elaborate work of George Agricola, a German scientist, who has been aptly styled the "father of modern mining-engineering;" and in the next century the German brothers Fugger successfully worked the abandoned mines of Spain. The German technical schools have of late years produced an army of able engineers, who, provided with modern appliances, and exercising a rigid and intelligent economy, have made the great German mines and smelting-works examples of the refinements of the arts of mining and metallurgy.

The principal seats of lead production in Germany today are the Rhenish provinces, Silesia, the Harz mountains, Nassau, and Freiberg in Saxony. The works of the Harz and Freiberg are government property;[1] the other mines are generally exploited by great corporations, who conduct their operations upon an enormous scale. The production of the German States in 1852 is estimated by Williams at fifteen to twenty thousand tons. It gradually increased to thirty to thirty-five thousand tons in 1861, to forty-nine thousand in 1867, and to seventy-two thousand tons in 1874. The increase continued uninterruptedly from 1875,

[1] Percy, The Metallurgy of Lead, p. 499; Williams, the Mineral Resources of the United States, 1885 and 1886.

when seventy thousand tons were produced; to 1885, when the total output was ninety-two thousand four hundred and eighty-five tons, — one company, the Mechernich, producing no less than twenty-three thousand four hundred and eighty tons.[1]

The discovery of America, and the booty secured by the Spanish conquerors of Peru and Mexico, directed the attention of the French people to their own stores of mineral wealth. Vestiges of ancient works were abundant in many districts, and it was thought to be only necessary to reopen the abandoned mines to secure the coveted treasure. A period of great activity in mining work was entered upon. Mines were exploited in many districts, and new and improved methods were introduced. The principal seats of mining enterprises at this epoch were in Bretagne, La Croix aux Mines, in the Vosges, Sainte Marie aux Mines, and Giromagny;[2] but the results did not realize the expectations of the projectors, and operations were gradually abandoned. During the time of the republic the Committee of Public Safety ordered an investigation of the mines of France, preparatory to the reopening of old and abandoned mines and the search for new deposits. Traces of ancient lead mines were found in many of the departments, but the work had been generally of a superficial character, and the ancient miners, by utilizing only the surface ores, had largely destroyed the usual indications. The report states that at that time — 1792 — the only lead ore mined was sold to the potters as alquifoux for glazing their wares, and that none was reduced to the metallic state.[3] Pomet, writing about a hundred years earlier[4] —

[1] See Percy, The Metallurgy of Lead, p. 499; also Williams, The Mineral Resources of the United States (for 1885 and 1886), from which the facts relating to modern works have been principally drawn.

[2] Leger, Les Travaux Publics, p. 775.

[3] Journal des Mines (Paris, 1792), vol. i.

[4] Pomet, History of Druggs, vol. ii. p. 351.

1694 — says: "Lead ore has no other use in France but for the potters."

Thus it appears that during the seventeenth and eighteenth centuries there was little or no mining of lead in France, and the production from her own ores to-day is comparatively insignificant. There are numerous and extensive lodes in the Vosges which have been opened for centuries, but owing to the adoption of an unwise policy, they have been generally abandoned. The only mine of any importance now being worked is that of the Pontigibaud Company, an English corporation, working the lead mines in Auvergne.

France does a large business in desilverizing, importing argentiferous ores and lead from Spain and Greece.[1]

In 1720 the House of Savoy became possessors of the Island of Sardinia, and upon the accession of Victor Emanuel II., the late King of Italy, mining operations were revived and pushed with great energy. The Sardinian mines are the principal sources of the lead produced in Italy to-day. Percy estimates the output of Sardinia in 1867 at twenty-three thousand two hundred and fifty-five tons, basing his estimates upon the returns of lead ore exported. Williams makes the production of Italy in 1885 about fifteen thousand tons, mostly refined at the works at Pertusola.[2]

Belgium has been a lead-producing country for many centuries, though never on a large scale. In 1867 her output has been placed at ten thousand three hundred and fifty-two tons, and in 1870 it was estimated at ten thousand tons, principally from her own ores; but her output has gradually declined, and in 1883, although eight thousand

[1] Percy, The Metallurgy of Lead, p. 338 ; Williams, The Mineral Resources of the United States (1885), p. 439 ; see also Karsten, System der Metallurgie.

[2] Percy, The Metallurgy of Lead, p. 499 ; see Karsten, System der Metallurgie, Berlin, 1837 ; also Mineral Resources of the United States (Washington, 1886), p. 270.

tons of lead were smelted, the amount produced from her own ores was insignificant.

Austria and Hungary have also produced lead for many centuries, but never in very large quantities. The mines at Bleiberg, near Villach, in Carinthia, have been celebrated for the extreme purity of their products. Next in importance are the mines of Przibram in Bohemia. The output of the Austro-Hungarian mines in 1867 was seven thousand six hundred tons, rising to about ten thousand tons in 1879, and to thirteen thousand tons in 1883.

The old Laurium mines in Greece were reopened in 1863 by a French company under a contract with the Grecian government. The old slag and scoriæ left by the ancient miners were reworked, and the product, together with the output of the mines, is shipped to France and to England for refining. The total output for 1881 amounted to ten thousand tons. It was probably greater in 1869, as during that year no less then eight thousand four hundred and eighty-three tons found a market in Great Britain alone.[1] The product in 1883 is estimated at about ten thousand tons.

In Norway and Sweden lead has been mined in modern times in limited quantities, but insufficient to supply the wants of those countries. The product may therefore be considered as unimportant.

The mineral resources of Turkey are abundant, but mining and metallurgy have received but little encouragement in that country. The argentiferous lead ores were worked by the ancients, but the shafts were not extended below the water level. In Turkey in Asia some argentiferous lead is produced, which was formerly cupelled at the mines. It is now desilverized at the mint in Constantinople, but it is inconsiderable in amount.[2]

[1] Percy, The Metallurgy of Lead, p. 499.

[2] See Mineral Resources of the United States, 1885, 1886.

The argentiferous lead ores in the Russian Empire have been exploited in modern times to a limited extent. The principal mines are in the Altai and Nertschinsk districts. In the Caucasus and in the Urals there are many deposits, some of which have been worked, producing lead in inconsiderable quantities. The latest statistics place the product of the Russian mines at one thousand one hundred tons in 1876, rising to one thousand four hundred tons in 1878, but gradually declining until 1882, when the output is placed at only five hundred and seventy-three tons.[1]

Japan is rich in mineral wealth. Mining was prosecuted in several districts of that country as early as the eighth century. The remains of ancient works give evidence of liberal enterprise in their construction and operation, and thus point to a former flourishing condition of the mining industry. A draining-level, eight thousand three hundred and seventy feet in length, was constructed to reduce the water in the lead mines of Hosakura. At the time of Pumpelly's visit to the mines of Japan but little work was being prosecuted. He visited the lead mines at Yurup, in the valley of the river of the same name, and at Ichinowatari, in the Island of Yesso. The absence of pumping apparatus to reduce the water prevented working at any considerable depth; the galleries are small, but well timbered, and until the introduction of the use of gunpowder by Pumpelly the only method practised of drifting through the rock was "by means of the hammer, pick, and gad." The ore is galena. It is powdered by means of stamps acting in stone-mortars and worked by a water-wheel. After being stamped the ore is washed and concentrated, this work being principally performed by women.[2]

[1] See Mineral Resources of the United States, 1886.

[2] R. Pumpelly, Across America and Asia (New York, 1871), p. 145.

In China lead occurs in many provinces,[1] but as it is imported in large quantities the production is probably unimportant. The Chinese Government has recently granted permission to work the mines in the province of Canton, and an enterprising native has leased a silver-lead mine at Tam'chow, and has begun the exploitation of the deposits on the Island of Lantao, near the city of Hong Kong. Mr. Consul Withers pronounces the galena exposed in the preliminary workings to be of good character.[2]

Lead is found in considerable quantities in Corea, and some mining is done by the natives, — no less than seven mines being worked at the date of the report of Ensign Foulk to the State Department. The country is believed by the Chinese and Japanese to be rich in minerals, but the government and people are unwilling to grant mining privileges to foreigners, and appear to be incapable of conducting extensive mining and smelting operations themselves.[3]

The ores of lead exist in considerable quantities in South Africa, and there are evidences in many places of mining by the natives. The exploitation is unimportant. The only notice found mentions one deposit, worked by an Englishman, who smelts the ore and supplies the local demand for ammunition.

Lead has been mined in Europe, and parts of Asia and of Africa from the earliest period of written history, and the supply, far from being exhausted, has furnished vastly increased quantities during the past half-century. Extensive as is the area which has been examined and exploited there is little doubt of the existence of vast virgin deposits

[1] R. Pumpelly, Geological Researches in China, etc. (Washington, 1866), p. 80 *et seq.*

[2] United States Consular Report, No. 65; Report of Consul R. E. Withers (Washington, 1886), p. 259.

[3] George C. Foulk, Ensign United States Navy, Report to State Department; Consular Report, No. 65 (Washington, 1886), p. 252 *et seq.*

in the mountains of Central Asia and Africa. The conquest of the comparatively unexplored portions of these continents by civilized nations, with the inevitable construction of railways and other improvements in means of communication and of transportation, will, doubtless, open up sources of supply now entirely unknown.

CHAPTER V.

LEAD MINING IN AMERICA.

THE glowing accounts of the early voyagers to the New World of the wonderful fertility of the soil and the mildness and salubrity of the climate inspired the London Company, the promoters of the settlement in Virginia, with the belief that a flourishing empire could be established there, which would not only immediately repay them for their outlay, but bring rich rewards for their enterprise. The belief in the existence of the precious metals in the country was universal, and it was thought that only colonization and exploration were needed to disclose and to secure untold riches. The immense wealth gained by Spain from her conquests in Peru and Mexico stimulated adventurers of other European nations to seek their fortunes beyond the sea. This greed for gold and belief in its attainment with little exertion assisted in no small degree the efforts of the London Company in securing settlers for their colony in Virginia. Writers of the period complain of the character of some of the early colonists. They constantly mention the lack of mechanics and working men. Needy adventurers, gentlemen out at elbows, broken merchants, and young men of more than questionable reputation, constituted a majority of the settlers. The charter of the colony, in conformity with the universal belief in the existence of the precious metals, contained provisions by the terms of which one-fifth of all

gold and silver, and one-fifteenth of all copper was reserved to the crown.

At the beginning of the second year of the life of the colony the managers of the company in London, having become impatient at the slow returns from their venture, imperatively demanded that a lump of gold be sent to them forthwith, on penalty of the abandonment of the colony.

The occurrence of shining particles in the soil, near Jamestown, was believed by some to indicate the presence of gold. They accordingly abandoned their useful occupations, filled a ship with the worthless dirt, and sent it to England.

Gold and silver were not found in the neighborhood of the settlement, but excellent iron ore abounded, and was discovered at an early date. No attempt to smelt this ore in a large way was made until the year 1620, when a furnace was erected at Falling Creek, not far from Jamestown. The next year the company sent out John Berkeley to take charge of the iron works. Berkeley was accompanied by his son and by twenty workmen skilled in mining and working metals. He assumed at once the direction of the works at Falling Creek. In May of the next year the entire settlement, of more than three hundred persons, with the exception of two children, who contrived to hide from the savages, was cut off and massacred by the Indians, and the furnaces and other improvements were utterly destroyed. The superintendent of the works, in his explorations in the neighborhood, had discovered a vein of galena, and had privately worked it in a small way, supplying the demand of his neighbors for bullets and shot.[1] His cupidity and greed prompted him to conceal

[1] The operations of this superintendent embraced the first mining and smelting of lead in America. Bishop: History of American Manufactures (Philadelphia, 1866), vol. i. p. 26.

the location of the vein, and when he was killed his secret died with him. The Indians very well understood the importance of this metal to the settlers, and would not disclose the location of the deposit; but some years later Colonel Boyd induced an Indian to reveal its position. The settlers at once took possession of the neighborhood, and supplied their needs from the mine for many years. Work has been done on this vein at intervals until comparatively recent times.

In the Dutch colony, at New Netherlands, by the terms of the charter under which the settlements were extended, all minerals were the special property of the Patroons. In 1646 a new charter was granted, by the terms of which the colonist who discovered minerals had the sole right to mine them for ten years, without the payment of any duty or royalty. Specimens of minerals found in the colony were sent to Amsterdam at an early date, and the home company directed the governor of the colony to equip and send out exploring parties in search of minerals. A company of German miners were sent out to the colony about 1730 by Baron Horsenclaver. These miners explored the district of the Highlands, and made many ventures in mining and smelting. This company, or other German miners, worked a vein of galena as early as 1740, near Northeast, in Dutchess County, and sent the ore to Bristol, England, and to Amsterdam.

In 1734 Governor Cosby announced a new discovery of lead ore in the colony, and sometime prior to 1740 a vein of argentiferous galena was discovered and worked at Ancram, Columbia County. Governor Clinton, in 1767, directed attention to the existence of valuable veins of lead ore in the colony, and stated that the British government had leased a mine of argentiferous galena to Mr. Frederick Philipse. A large refinery of lead or of iron

existed at Sing Sing, prior to or at the beginning of the Revolution.[1]

The Massachusetts colonists were not very sanguine of the existence of the precious metals in their domain, yet they did not neglect to encourage manufactures and the search for minerals. The failure to find indications of the noble metals, or perhaps the disappointment occasioned by the discovery that minerals found by some ignorant adventurers, and asserted to contain gold, proved to be common ores of iron, suggested to the Court of Assistants, in London, the propriety of sending over experienced miners and metallurgists to explore the country in a scientific manner. They accordingly engaged the services of Thomas Graves, "a man experienced in iron workes, in Saltworkes, in measuring and surveying of lands, and in fortifications, in lead, copper, and alum mynes," to visit the Massachusetts colony, "and to exercise his scientific qualifications." In a report made in 1632 on the minerals of New England, lead ore and red-lead are mentioned.[2]

A vein of argentiferous galena was known to exist at Southampton, Mass., as early as 1754, and, according to Bishop, lead was mined at Worcester in the same year.[3] The deposit at Southampton was worked by a company from Connecticut in 1765, and "masses of ore weighing as much as two hundred pounds were taken out."[4]

John Winthrop, Jr., son of Governor Winthrop, of Massachusetts, was commissioned in 1643 by Lord Saye and Sele and Lord Brooke to build a fort in Connecticut. In that year he received a grant of land for a settlement and for the erection of iron-works, and about the same time

[1] Bishop, History of American Manufactures, vol. i. pp. 527, 533.
[2] See Bishop, History of American Manufactures, vol. i. p. 470.
[3] Bishop, History of American Manufactures, vol. i. p. 493.
[4] Whitney, Metallic Wealth of the United States, p. 390.

was granted the hill at Tantonsq, "where the blacke leade is." In 1645 he resided at Pequod (New London); and in 1651, at his suggestion, the Assembly of Connecticut passed an act for the encouragement of the search for ores and the development of the mineral resources of the colony. The preamble of this act is as follows: "Whereas in this rocky country, among these mountainous and rocky hills, there are probabilities of mines of metals, the discovery of which may be of great advantage to the country in raising a staple commodity; and, whereas, John Winthrop, Esqr., doth intend to be at charge and adventure for the search and the discovery of such mines and minerals: for the encouragement thereof, and of any that shall adventure with the said John Winthrop, Esqr., in the said business, it is ordered," etc. The act granted to Winthrop the lands, wood, timber, and water within two or three miles of any mines of lead, copper, tin, antimony, vitriol, black-lead, alum, etc. There are no records of the result of Winthrop's operations; but the lead deposits near Middletown were afterwards specially granted to him, and vestiges of ancient mining there indicate that they were worked many years prior to the Revolution. In 1663 the General Court ordered that any person who would undertake the discovery of any mines or minerals, and purchase them for the country, should be honorably rewarded "out of what he did discover." [1]

The existence of metalliferous deposits in Pennsylvania was known at the time of the Swedish settlement on the Delaware under Printz, and extensive explorations, and perhaps mining, were prosecuted in the neighboring mountains. In the Bald Eagle, or Sinking Spring, valley, in Huntingdon County, lead mining operations were conducted

[1] J. G. Palfrey, History of New England (Boston, 1859, 3 vols.), vol. ii. p. 233 *et seq.;* Bishop, History of American Manufactures, vol. i. 505; Whitney, The Metallic Wealth of the United States, 393.

in early times, possibly by the French, in their search for the precious metals, or by the early settlers.

Lead was known to exist in Maryland, near Unionville, prior to the Revolution, but there are no records of its exploitation.

Shortly after the outbreak of hostilities with the mother-country the attention of Congress was directed to the necessity of providing prompt and efficient supplies of ammunition to the Continental troops. The Committee of Public Safety urged the local governments of the colonies to encourage manufacturing enterprises, the search for ores, and the mining and smelting of lead. In 1775 a committee in South Carolina offered rewards and assistance to those engaged in the manufacture of military supplies. Among other rewards offered was one of £500 to the proprietors of the first works for manufacturing or smelting lead, to be paid so soon as one thousand pounds was produced; £200 were to be paid to the second, and £100 to the third establishment when they had produced an equal quantity.[1]

The mines at Northeast, in Dutchess County, New York, which had been abandoned, were reopened during the Revolution by Peter McDaniels, who was encouraged by the Committee of Public Safety. These mines were again abandoned at the close of the war. In December, 1775, a loan of £200 was granted to Frederick Gaunt to assist in working a lead mine near the Fredericktown mountains in Maryland. In Connecticut, at the outbreak of hostilities, mining was being prosecuted at the Middletown deposits, and at the request of the Committee of Congress the Assembly promptly appointed a committee, who were authorized to purchase the ore already raised, and to encourage a vigorous prosecution of the work. The committee sent to other colonies for a person skilled in smelting

[1] Bishop, History of American Manufactures.

and refining, and found a German named Fedaband. They were unsuccessful in securing his services, as it proved he was under a pledge to the King not to refine metals in America. A refiner and smelter was afterwards found and engaged. At Fincastle, Virginia, and on the Great Kanawha, lead mines were worked during the Revolution. The produce of these mines was extremely limited, not exceeding twenty-five tons per annum. In 1778 Colonel Roberdeau erected a fort near the Sinking Spring Valley mines in Pennsylvania, and mined and smelted lead for the State. The flooding of the mines and the persistent hostility of the Indians soon caused the work to be abandoned.[1] In October, 1777, the Board of War was instructed by Congress to urge upon the government of New York the importance of working the lead mines in that colony. "During the scarcity of lead in 1778," Bishop says, "General Armstrong informed President Wharton, of the Pennsylvania Assembly, that Mr. Husbands, a member of the Assembly, had knowledge of a mine of lead near Frankstown, on land formerly surveyed for the Penn family."[2]

Operations at the mine in Southampton, Mass., were abandoned during the Revolution. Work was resumed in 1809, but as it progressed the hopes of the projectors that the vein would open out into paying ore gradually faded, and in 1828 work was again suspended. In 1815 Professor

[1] See Bishop, History of American Manufactures, vol. i. p. 565 *et seq.*

[2] Bishop, History of American Manufactures, vol. ii. p. 328. As the war progressed the supplies of lead became exhausted, and the production of the mines proving entirely inadequate, the Continental troops were driven to such straits for want of metal for their bullets that recourse was had to domestic articles of pewter, which were contributed by patriotic citizens; these with the leaden gutters from the houses were melted up. There is a tradition in Cambridge, Mass., that the pewter organ-pipes of the old church and the leaden coat-of-arms from the table grave-stones in the old churchyard were melted and cast into bullets for the Continental troops during the siege of Boston.

Silliman says of this mine: "The lead mine at Southampton is becoming an object of considerable curiosity and importance; whether it will be profitable to pursue it is doubtful. The level has already been the work of four years, and two more will be required to complete it."[1] Work was again resumed here in 1862, and prosecuted for some months with considerable energy; although large sums were expended in sinking shafts and in drifting, ore in paying quantities was not found. There are several veins of galena in the neighborhood of Southampton, but none of sufficient promise to warrant the cost of opening them.

Lead ores occur in inconsiderable quantities in Maine, and the Lubec lead mines were opened in 1832 with unimportant results. In Vermont galena is found in thin veins in several places. In New Hampshire lead ore occurs at Shelburne, where a mine was opened in 1846, and worked until 1849. The Eaton lead mines were opened in 1826. The ores of lead have not been found in these States in paying quantities, and the operations above-mentioned resulted disastrously.

The deposits near Middletown, Conn., were reopened in 1852 by the Middletown Silver and Lead Mining Company, but the enterprise was soon abandoned, the results being far from satisfactory. Galena occurs in Brookfield, Conn., where a mine was opened previous to 1850; but the deposit, though rich in quality, proved insufficient in quantity to pay for working. At Monroe and at Plymouth mines of lead were opened many years since, but the ore was not found in economic quantities. Galena occurs at Canaan, and at several other localities in the State.

The deposits of lead in St. Lawrence County, New York, attracted considerable attention fifty years ago. The Ros-

[1] American Journal of Arts and Sciences, vol. i. p. 335.

sie mines were opened in 1835 by two companies, — the Rossie Lead Mining Company, and the Rossie Galena Company. During 1836 and 1837 large quantities of very rich ore were taken out, yielding some two thousand one hundred tons of lead. In 1839 the product was but six hundred tons, and in 1840 it fell to two hundred tons. The richest ores being already secured, and water becoming troublesome, the mines were then abandoned. In 1852 work was resumed at this locality by the Great Northern Lead Company, but again abandoned after the capital of the company had been exhausted in clearing out the mine, and before any profitable result had been reached. Lead mining has been prosecuted in Herkimer, Sullivan, Montgomery, and Ulster counties, and in other localities in the State, and considerable ore has been obtained; but the work has generally proved to be unprofitable, and mining for lead has been abandoned.

The ores of lead occur in Montgomery and Chester counties, in Pennsylvania, and extensive exploration and development has been undertaken by several companies. The results have not been quite satisfactory however, and the product has been unimportant. In 1828 a premium was awarded at a fair of the Franklin Institute, Philadelphia, to S. P. Wetherill & Co. for one thousand pigs of lead, the produce of the Perkiomen mine. In North Carolina a vein of argentiferous galena was discovered in 1836 in Davidson County, and considerable work was done in development. Mining operations were conducted at intervals until 1852, but the quantity of lead produced was inconsiderable.

The lead deposits near Fincastle, Virginia, have been worked from very early times. The ore is found distributed through the clay and in the rock; it is argentiferous, and yields about sixty per cent of lead. A vein of ore in Wyethe County, on the Great Kanawha, had

been worked for many years prior to 1850. The furnace was on the opposite side of the river. The ore was hauled to the bank in wagons, ferried across the river in canoes, and thence hauled in wagons to the furnace. From the furnace the lead was transported in wagons one hundred and thirty miles to the James River, and thence by water an equal distance to a point a short distance above Richmond. These mines were worked quite extensively during the last century, and furnished lead to many parts of the Union.[1] Lead mines were also opened in early days in the district between the Alleghany and Cumberland mountains. Lead occurs in many parts of Kentucky, and mining has been carried on in several districts, but the explorations have so far failed to disclose deposits of value.[1]

Lead exists in the mineral region in the neighborhood of Lake Superior. One vein in Canada, at Thunder Bay, has been traced for a great distance. The developments have so far failed to disclose deposits of lead of great richness, and the production has been unimportant.

The abundance of lead ores in Missouri, Illinois, Wisconsin, and Iowa, and the ease with which the pure ores of this region are smelted would lead one to suppose that lead would be very frequently found in the mounds of the aboriginal inhabitants which stud the broad bottoms of the Ohio, Mississippi, and their tributaries, in great numbers. Such is not the case however; galena has repeatedly been met with, and what has been termed galena money has been found in a few localities among the Ohio mounds, but the metal is rarely found. Foster refers to a fractured pipe, found in a mound in Wisconsin, which had been mended with a ferule of lead, and a piece of this metal is

[1] See Whitney, Metallic Wealth of the United States, p. 384 *et seq.;* also Bishop, History of American Manufactures, p. 564 *et seq.*

said to have been found in a mound in Illinois.[1] Bancroft thinks the mound-builders were ignorant of the arts of smelting, casting, and of welding.[2] The Marquis de Nadaillac is of the opinion that there is no conclusive evidence that the art of smelting was understood by them.[3] Squier and Davis say, "From the presence of galena in the mounds it seems almost impossible that the builders could have been ignorant of the manufacture of lead;" but they refer to one find only of the metal, and that under such circumstances as to make its origin and date extremely doubtful.[4] In reply to an inquiry upon this subject Prof. F. W. Putnam, of the Peabody Museum of American Archæology and Ethnology, writes as follows: "In all the explorations of mounds and ancient burial-places in America, which I have made or known about, I have never found evidence of the use of lead, except in the form of crystals of galena; these I have found several times in the mounds; they evidently were collected simply as ornaments, or on account of their bright color and other peculiarities; a few have been slightly cut. Of course, all that I have found have been thickly coated with a white oxide. There is not the least evidence (in North America), so far as I know, of lead having been melted or smelted, or used by melting, until after white contact. Our North Americans, north of Mexico, were undoubtedly acquainted with native silver, gold, copper, and iron (meteoric), but there is no evidence of their working these metals except by hammering."

[1] J. W. Foster, LL.D., Pre-historic Races of the United States (Chicago, 1873), p. 271.

[2] H. H. Bancroft, Native Races of the Pacific States (New York, 1875), vol. iv. p. 778.

[3] Marquis de Nadaillac, Pre-historic America, translated by N. D'Anvers, edited by W. H. Dall (New York and London, 1884), p. 181.

[4] Squier and Davis, Ancient Monuments of the Mississippi Valley (New York, 1848), p. 208.

The French of Canada, in their explorations of the Great West, discovered the copper deposits of Lake Superior, and their missionaries, hearing of the great river to the westward, soon penetrated to that region. The expeditions and journeys of Marquette, Joliet, La Salle, and their followers, up and down the Mississippi, must have familiarized the Indians — if they were not already acquainted with them — with the properties and value of lead. Joutel, in his relation or journal of La Salle's last voyage, mentions the occurrence of lead in the Upper Mississippi in such a manner as to show that its existence in the country was well known to the French;[1] and it is stated that, as early as 1690, the Indians occupying the district in the neighborhood of the present town of Galena, sold lead of their own smelting to the traders at the French trading-post where the city of Peoria now stands.

Nicholas Perrot, an Indian trader, and sometimes employed as an Indian agent by the French government in Canada, made several journeys into the country of the Illinois, and of other tribes, at an early period, and is said to have discovered the lead mines above the river Des Moines. Penicaut, who accompanied Le Sueur in his voyage in 1700 from New Orleans to the Upper Mississippi, says, "These mines are known to this day by Perrot's name."[2] Le Sueur, in his narrative of his voyage to "the great copper mines of the Upper Mississippi," mentions the existence of lead mines "on the prairie, about a league inland," and near a little river which he named "Rivière à la Mine."[3] This river was called by the first settlers Rivière de Fève, or Bean River, so named on account of

[1] B. F. French, Historical Collections of Louisiana and Florida, part i. (New York, 1846), p. 186.

[2] B. F. French, Historical Collections of Louisiana and Florida (New Series, New York, 1869), p. 68.

[3] J. G. Shea ed. Early Voyages Up and Down the Mississippi; Le Sueur's Voyage (Albany, 1861), p. 94.

the wild beans which grew upon its banks. This name has been corrupted into Fièvre, or Fever, River, by which it is known to-day. The French were persistent in the belief that gold and silver existed in the country, but they did not altogether neglect the search for the baser but more useful metals. Jucherau, about 1702, was granted permission to proceed to the Mississippi to establish tanneries, and to mine for copper and lead. This explorer founded a settlement upon the Ouabache.

Carver, in his account of a journey to the headwaters of the Mississippi, in 1766, says: "The lands near the junction of the Ouisconsin and the Mississippi seemed to be excellent, but at a distance it is full of mountains, where there are said to be many lead mines."[1]

This territory was occupied by the Sacs and Fox Indians, and they were probably the only miners and smelters of lead in that region until 1774, when Julien Dubuque settled among them, establishing himself at a point near the site of the flourishing city which now bears his name. Dubuque was a French Canadian, and first settled at Cahokia, a French village situated on the left bank of the Mississippi, opposite the bluff on which the city of St. Louis now stands. He was a man of determined character and keen perceptions; he possessed a thorough knowledge of the Indians, and soon acquired a marked influence over his new friends. He was believed by this people to possess a cure for the bite of the rattlesnake, and was held in such veneration and esteem that they submitted all matters of great importance to him, and absolutely refused to allow any other white man to live among them. At a full council of the Fox tribe, held at Prairie du Chien in 1788, they granted to Dubuque, under his Indian name of "La Petite Nuit," a mine of lead. This grant was confirmed to him,

[1] S. Carver, Travels Through the Interior of North America (London, 1778), p. 49.

in 1796, by the Baron de Carondelet, the Governor-General of Louisiana.

From this period until his death, in 1809, Dubuque worked these mines, but it is impossible to arrive at any trustworthy estimate of the amount of metal produced. General Pike failed to get any satisfactory information from Dubuque at the time of his visit, in 1805, either as to the particulars of his grant from the Baron de Carondelet, or as to the amount of lead produced at the mines. Dubuque said that his grant was at St. Louis in the possession of Mr. Soulard, and that it covered a territory extending twenty-eight leagues in length, by one to three leagues wide; that the product of the mines was twenty thousand to forty thousand pounds per annum; and that the yield of lead was about seventy-five per cent. General Pike appears to have been of the impression that Dubuque was unwilling to give him the desired information, and considered that the replies to his questions were not entirely trustworthy.[1]

Dubuque died in 1809, and his Indian friends, it is said, placed him in a leaden coffin, buried him on the bluff which bears his name, and for many years kept a lamp burning nightly over his grave. Dubuque died in debt, and his mines were seized by his creditors, and were sold for their benefit. The Indians, however, denied all former concessions, and a dispute arose, which was unsettled for many years.[2]

After Dubuque's death the Indians remained in posses-

[1] Gen. Z. M. Pike, Account of an Expedition to the Sources of the Mississippi, etc. (Philadelphia, 1810), appendix, p. 5.

[2] Bradbury relates the story of the fate of the persons who bought Dubuque's claim. They ascended the Mississippi with an armed party to take possession, but were roughly treated by the Indians, who immediately sent deputies to St. Louis to plead their cause. They disclaimed having had any intention to continue the grant beyond the life of Dubuque, and declared their unwillingness to offend the government of the United States. They said that when the Great

sion of the mines, refusing to allow any white man to enter upon them, evidently entertaining a high opinion of their value. Schoolcraft, writing in 1819, says, "The Sacs and Foxes are still in possession of the mines of Prairie du Chien,"[1] and they continued to claim their rights until their removal from the district in 1832.

In 1807 Congress passed an act by virtue of which all government lands bearing lead ores were reserved, and leases of these lands were authorized. None were issued, however, until 1822,[2] and but little mining was done under these leases until 1826, after which time the production began to increase. Upon the final withdrawal of the Indians from the territory, in 1832, the legal representatives of Dubuque took possession of the lands under his grant from De Carondelet, and began extensive improvements. The government, however, claimed the land by virtue of a subsequent purchase from the Indians, and in 1833 they forcibly ejected the settlers.

The first leases of these lead-bearing lands by the government provided that ten per cent of the lead produced should be paid as rent. This amount was afterwards reduced to six per cent; but shortly after fresh troubles arose, and in 1847 it was determined to sell the mineral lands.

There are no trustworthy records of the production of these mines during this early period. It is claimed that in 1811 the Indians sold more than five hundred thousand

Spirit gave the land to the red men, their ancestors, he foresaw that the white men would come into the country and that the game would be destroyed. He therefore put lead into the ground that they, their wives and children, might continue to exist. JOHN BRADBURY: Travels into the Interior of America (Liverpool, 1817), p. 256.

[1] H. R. Schoolcraft, A View of the Lead Mines of Missouri, etc. (New York, 1819), p. 62.

[2] For information respecting the condition of mineral lands and form of lease, see message of President Monroe to Congress, May 7, 1822 (Washington, 1822).

pounds of lead to the traders, and that from 1821 to 1823 three hundred and thirty-five thousand one hundred and thirty pounds were produced, chiefly by the Indians. Large quantities were raised in 1828 and 1829, but the business was overdone at this time, and for a year or two it declined in importance.[1]

The mining and metallurgy of this region, previous to 1845, was of a very primitive character. The deposits being rich, and occurring near the surface, extensive mining plants were unnecessary; only the surface mineral being worked, or that lying above the water level, no implements were required other than the pick, shovel, and a rude windlass.

The settlement of the legal questions affecting the lands in the district, and the signs of exhaustion of the surface ores made, after 1847, a more careful working of the mines, and a more complete reduction of the mineral necessary; but notwithstanding the improvements which were then made, the production has gradually and steadily declined, until now it is unimportant as compared with the immense output of Colorado and other States beyond the great plains.

In answer to an inquiry relating to the present condition of the lead mines of the district, which comprises portions of the States of Illinois, Wisconsin, and Iowa, in the vicinity of Galena, Ill., Mr. James M. Ryan, of that city, who has been intimately connected with the lead-mining industry for many years, says: "The annual product of the Galena mines, since 1880, will average about fifty thousand pigs, or two thousand tons. In 1885 the product reached fifty-five thousand pigs. There have been some new discoveries made during the past year, only one of which is known to be upon hitherto unexplored ground. Our mines

[1] Bishop, History of American Manufactures, vol. ii. p. 287.

are yielding very well, considering their extent, most of the land being now used for agricultural or grazing purposes, and not open to mining. Our mines are by no means exhausted, but, on the contrary, are rich in lead ore. The western mines have attracted many men who formerly worked our mines, and the lands have been gradually fenced in and devoted to agricultural purposes, thus contracting the territory open to mining very much as compared with twenty or thirty years ago." Mr. Caswell estimates the production of the Galena district in 1886 at one thousand five hundred tons.

Extensive metalliferous deposits exist in Southern Illinois, notably in Hardin County, near the village of Rose Clare. These deposits consist of several veins, declared by Raymond, who reported on the property in 1874, to be true fissure veins, which can be traced across the Ohio and into the State of Kentucky. These veins consist of calc spar and fluor spar, in which zinc blende and galena are disseminated. The galena occurs in small chimneys, or chutes, irregularly scattered through the vein, constituting perhaps twelve per cent of the whole mass, and carries eight to fourteen ounces of silver to the ton. The veins in some cases are as much as twenty feet thick, and if the galena is disseminated through the whole mass the amount is very large. These deposits have been known for many years, and have been exploited at different times by individuals and companies, but without successful financial results. The operations have been restricted for want of sufficient capital, and the methods employed have been generally crude and unscientific. Several furnaces for smelting the ore have been erected, and smelting has been conducted in a small way, but the plant is not of sufficient capacity for profitable results, and the design of the furnaces is not perfectly adapted to the requirements of the ore. As a consequence the production has been in-

significant, and, after some desultory work, smelting was abandoned many years ago.[1]

The explorations of the Canadian Jesuits resulted in the acquisition of the Great West by the French crown. That portion of it, which is now included in the States of Missouri, Arkansas, Mississippi, Louisiana, parts of Illinois, Tennessee, and Kentucky, and the broad domain to the westward was known as Louisiana. The most marvellous tales of the mineral wealth of this new country were circulated throughout France, rousing the enthusiasm of the people, until it was believed that the new possessions needed only exploration and colonization to bear fruits rivalling the enormous spoils of the Spanish conquests of Mexico and Peru.

On Sept. 14, 1712, letters patent were granted (for a money consideration, it is said) by Louis XIV. to Anthony Crozat for exclusive commercial privileges in Louisiana, with proprietorship of all mines and minerals, reserving one-fifth of all gold and silver, and one-tenth of all baser metals for the crown. Crozat was also granted exclusive privileges for traffic in slaves in the territory, and was permitted to send one ship in each year to the coast of Guinea for a cargo of these unfortunates.

Vessels were at once freighted with colonists and supplies for the new colony, and upon his arrival Crozat prepared to open trade with the Indians for peltries. Unexpected difficulties however presented themselves in the competition of the English traders who penetrated to this distant

[1] Report of Dr. R. W. Raymond on Property of Mineral City Mining and Smelting Company, 1874. Fluor spar is now mined here in a small way, and efforts are being made to provide capital sufficient to develop the property and to produce lead on a large scale. The report of Dr. Raymond is encouraging, and should the property fall into the hands of a company possessing large capital, and the exploitation be pushed with vigor by competent engineers, the locality would doubtless become an important source of the lead supply of the United States.

region, and in the hostility or indifference of the Spanish traders at Pensacola. On the 17th of March, 1713, there arrived in Mobile Bay the frigate "Baron de la Fosse." Among her passengers was M. de la Motte Cadillac, or La Mothe Cadillac, with a commission as governor. La Mothe Cadillac, or Lamothe, as he signed his name in a clear bold hand, — such a signature as many a merchant prince may envy, — Parkman describes as a *gentilhomme* rover, one who as chief of a band of hardy adventurers was ever ready for a desperate dash into unknown dangers, sometimes engaged in contraband trading, at others penetrating into new and undiscovered regions, fighting, negotiating, and establishing new forts or settlements.[1] Lamothe, or La Motte, as he is generally called in the literature of the period, arrived in Canada from France with La Salle in July, 1678. He took an active part in the journeys of discovery made by the French, and accompanied Hennepin in his expedition to Niagara and to the Iroquois. La Motte founded Detroit, and engaged in the expeditions for the capture of the English settlements on the coast of Maine.[2]

La Motte seems to have been in a continual quarrel with the priests, and was in bad repute with the faithful of Montreal, who protested against the establishment of the post at Detroit, alleging that La Motte was "known not to be in the odor of sanctity." He was fully imbued with the spirit of the times. While he was commandant at Michillimackinac an Iroquois prisoner was tortured and burned at the stake, and by his orders cut up and distributed as a choice morsel to his Indian allies. He prom-

[1] Francis Parkman, The Old Régime in Canada (Boston, 1874), p. 261.

[2] A Description of Louisiana, by Father Louis Hennepin, Récollet Missionary, translated by J. G. Shea (New York, 1880), p. 61. See Voyages Curieux et Nouveaux de Messrs. Hennepin et Delaborde, etc. (Amsterdam, 1740), p. 77; also see Le Clercq, First Establishment of the Faith in the New World, translated by J. G. Shea (New York, 1880), vol. ii. p. 299 *et seq.*

ised to renew the entertainment should more prisoners be brought in.[1]

La Motte found upon assuming the duties of his office that the privileges of trading granted by the King to Crozat restricted his authority and the importance of his position. So restless a nature could not accept inactivity, and in 1715 he embarked upon an expedition to the country of the Illinois in search of silver mines. The belief in the existence of silver and gold in the country was universal. Du Pratz, writing so late as 1758, says, "I found upon the river of the Arkansas a rivulet that rolled down with its waters gold dust," and, "The mine of Marameg, which is silver, is pretty near the confluence of the river which gives it name."[2] Brackenridge, writing in 1810, seems to have believed in the existence of gold in Arkansas and of silver in Missouri.[3] Bradbury, however, a companion of Brackenridge in his journey up the Missouri, and writing at about the same time, expresses surprise that Du Pratz should insist that a silver mine existed in the country.[4]

La Motte returned from his expedition to the Illinois, bringing fine specimens of lead ore, but no silver or gold.

It is supposed that upon this expedition La Motte discovered the deposits of lead upon the head waters of the St. Francis River, which bear his name to-day, and are known as Mine La Motte.[5] Authorities generally place the dis-

[1] Francis Parkman, Count Frontenac, and New France under Louis XIV. (Boston, 1880), p. 403 *et seq.* See also Narrative and Critical History of America, edited by Justin Winsor (Boston and New York, 1886), vol. v. p. 29.

[2] Le Paye Du Pratz, The History of Louisiana, etc., translated by —— (London, 1774), pp. 177, 219.

[3] H. M. Brackenridge, Views of Louisiana (Pittsburgh, 1814), p. 63.

[4] John Bradbury, Travels in the Interior of America, etc. (Liverpool, 1817), p. 250.

[5] Some writers have attempted to show that De Soto reached the mineral region of Missouri in his expedition of exploration and discovery in 1539–41. It is contended with some degree of probability that De Soto first discovered the Mis-

covery of these deposits at a later date. Schoolcraft says La Motte was sent out by Renault in 1720 to search for mines, and at this time discovered Mine La Motte;[1] but La Motte resigned, and surrendered his office to L'Epinay in March, 1719, and returned to France, where he died in the succeeding year.[2] There is a tradition among the old inhabitants of the district that La Motte had learned at Kaskaskia that the Indians had brought in lead to barter for supplies. La Motte endeavored by presents and promises to persuade them to disclose the location of the deposit. After much negotiation the Indians consented, and, accompanied by La Motte and a guard of five men, they started for the mines. La Motte suspected that the Indians would refuse at the last moment to show him the vein, and instructed his men, should the Indians declare they could not find it, to leave the camp singly and in different directions, and search for the locality. As La Motte had surmised, after penetrating to some distance in the country, the Indians said they were unable to find the deposit. La Motte went into camp, and shortly after, making various excuses, his men one by one left the camp. After a search, occupying a day or two, they returned, having found the deposit called in later times "The Golden Vein," one of the richest deposits of galena ever discovered.[3]

Charlevoix tells us the Indians believed they would

sissippi River at a point near the northwestern corner of the State of Mississippi, where he crossed to the Arkansas shore. He toiled through the swamps and low lands of southeast Missouri, striking north till he reached a country which is supposed to be the mineral region near Arcadia, and not far from Mine La Motte. Schoolcraft treats this subject at some length, and presents facts and arguments in support of the proposition, which seem to be conclusive. See H. R. Schoolcraft, Scenes and Adventures in the Semi-Alpine Region of the Ozark Mountains of Missouri and Arkansas (Philadelphia, 1853), p. 139 *et seq.*

[1] Schoolcraft, Views of the Lead Mines, etc., p. 16.

[2] See Du Pratz, History of Louisiana, p. 12 ; B. F. French, Historical Collections of Louisiana (New Series), p. 112.

[3] Mr. V. R. Allen, of Mine La Motte, has furnished this and other interesting traditions and information respecting the early history of Mine La Motte.

certainly die should they reveal the location of their mines to a stranger.[1] The existence of lead in the region watered by the Meramec had been known to the French for some years. The Indians had offered it in barter for supplies at the French posts of Kaskaskia, and Cahokia; and Penicaut, one of Le Sueur's followers in his voyage up the Mississippi, in 1700, in his account of the journey says: "We came to a small river called Maramecq. It is by this route that the Indians go to the lead mines, which are about fifty leagues distant up the Mississippi; ten leagues further we came to a village of the Illinois, situated on the banks of the river."[2] The lead mines referred to must be those of southeast Missouri, which are perhaps fifty leagues distant by the course of the Meramec and its tributaries, while the mines on the upper Mississippi are more than one hundred leagues from the Indian village, which was located upon the low lands opposite the rocky bluff upon which the city of St. Louis was afterwards founded. Grevier mentions in his journal the river Miaramigoiia, "where the very rich lead mine is, twelve or thirteen leagues from its mouth."[3]

Crozat's scheme proved too much for his resources, and in 1717 he surrendered his privileges. In September of the same year the charter of the Company of the West was registered in France. This company was established by the celebrated adventurer John Law, as a means of relief to the French exchequer, which at that period was struggling with an immense floating debt. The privileges surrendered by Crozat were at once granted to the new company, and these concessions were followed soon after by other grants

[1] Père Fr. X. Charlevoix, Journal of a Voyage to North America, etc. (London, 1761, 2 vols.), vol. ii. p. 219.

[2] B. F. French, Historical Collections of Louisiana (New Series, New York, 1869), p. 65.

[3] Journal of the Voyage of Father Grevier in 1700 Down the Mississippi; Shea's Collection of Early Voyages on the Mississippi (Albany, 1861), p. 119.

and by the absorption of other commercial companies. The title was changed to the *Compagnie des Indes*, and the speculative bubble which made all France mad was fairly launched. Under the excitement which followed the establishment of this company Louisiana received large accessions to its population. As the belief in the existence of the precious metals was universal no great difficulty was experienced in persuading miners and artisans to emigrate to the new Eldorado. A settlement had been made in 1700 at Kaskaskia, and in 1718 the company built Fort Chartres, on the Mississippi, a short distance above.

In 1718 the Company of St. Philippe was formed, under the patronage of the Company of the West, for trading and mining. As director and agent of this company, Phillippe François Renault, left France in 1719 with two hundred French miners and smelters, bound for the gold and silver mines of the Meramec, St. Francis, and the Arkansas. Renault stopped at San Domingo to purchase five hundred slaves to work his mines, and then proceeded to Kaskaskia in Illinois, and immediately dispatched parties in different directions in search of gold and silver ores. The deposits of lead on the St. Francis, discovered by La Motte, presented peculiarities which led the first explorers to believe that the ore contained silver, and the failure to extract the precious metal was attributed to the refractory condition of the ore, which required peculiar manipulation in treatment for successful reduction. Le Page Du Pratz, who arrived in the colony in 1719, and who wrote a history of Louisiana in 1758, locates a gold mine on the headwaters of the Arkansas, and refers to "De la Mothe's mine" as a silver mine, "the assay of which has been made."[1] Austin, writing in 1804, says that the ore

[1] Du Pratz, History of Louisiana, p. 182.

obtained from Mine La Motte contains fifty ounces of silver to the ton.[1]

Renault headed one of his exploring parties, and is said to have discovered the lead-fields in the neighborhood of the town of Potosi, in Missouri.

According to Charlevoix, who passed down the river in 1721, the first attempt at mining in this region was made by the Sieur de Lochon in 1719, who was sent into the country by the West India Company as principal smelter or founder. The object however was silver, and not lead. De Lochon mined a quantity of ore, and after four days smelting produced from a pound of ore two drachms of silver. Some, however, suspected that the smelter surreptitiously added the precious metal, which was probably the fact. He afterwards succeeded in recovering "fourteen pounds of very bad lead" from two or three thousand pounds of ore, and disgusted with his failure left the country and returned to France.

The company still believing in the existence of precious metals, and that the failure of De Lochon was only due to his ignorance of smelting, sent out a Spaniard named Antonio, who had been taken prisoner at the siege of Pensacola, had afterwards been a galley-slave, and who boasted of his experience in mining in Mexico. Antonio succeeded no better than his predecessor. He made extensive excavations, smelted pieces of the rock, and it was said succeeded in extracting some silver, but this statement was not verified. A company of miners, under the lead of one La Renaudière, now took charge of the operations. These adventurers met with the same ill success, because, Charlevoix says, neither La Renaudière nor any of his company were in the least acquainted with the construction of furnaces. About this time Renault arrived with his party

[1] American State Papers, — Public Lands, vol. i. p. 188: Letter of Moses Austin to Captain Stoddard.

of exploration and discovery, and undertook the development of the deposits and the search for silver. "In the month of June last" (1721), Charlevoix says, "Renault found a bed of lead two feet in thickness, running to a great length over a chain of mountains, where he has set his people to work. He flatters himself that there is silver below the lead. Everybody is not of his opinion, but time will discover the truth."[1]

Renault's discovery was afterward granted to him in freehold, — a princely domain, "a league and a half in front, on the little Maramig and on the River Maramig, at the place of the first fork, which lead to the cabin called *Cabanage de Renaudière*, depth six leagues." This grant is signed "Boisbriant Des Ursins," governor or commandant at Fort Chartres. Renault's exploration, however, was for the discovery of silver, and failing in this he set his men to *digging* lead ore at what was afterwards known as Mine Renault, situated near Potosi. Austin, in 1804, says, "This mine has not been worked in seventy years."

The Mississippi scheme collapsed in 1731, and Renault, having previously discovered many deposits of lead, and failing to find silver, turned his attention to the production of the baser metal. His operations were not successful, and he gradually withdrew from his mining ventures, sold his slaves, and in 1744 returned to France, where he died in 1755.

In 1763 François Vallé explored the deposits at Mine La Motte, and erected a block-house to protect his men from the raids of the Chickasaws, who frequently carried the tomahawk and torch through the country. Vallé conducted mining operations for some years; but in 1769, during the absence of a portion of the force, the post was

[1] Père Fr. X. de Charlevoix, Journal of a Voyage to North America, etc. (London, 1761, 2 vols.), vol. ii. p. 219 *et seq.*

attacked by the Indians, and Vallé's favorite son was brutally murdered. The mines were then abandoned, but after a short time operations were again inaugurated; but another attack resulted in the capture and torture of La Bastille, one of Vallé's followers, when the work was again abandoned, and it was not resumed until 1780 or 1782. This last attempt was successful, and the deposit has been exploited nearly continuously ever since.

In 1763, Francis Burton, or Breton,[1] discovered the extensive lead fields known as Mine à Burton. In 1798, a concession of one league, comprehending about one third of the deposits, was made to Moses Austin, on condition he should erect a smelting-furnace and establish lead manfacture. Previous to the operations of Austin, the methods in use for mining and smelting were crude and wasteful in the extreme. Austin erected a reverberatory furnace of approved form, sunk the first shaft known in the territory, and erected at Herculaneum, a town he founded on the Mississippi, a shot-tower and sheet-lead works.[2] He disposed of his products to New Orleans and the settlements on the river below. About this time many important discoveries were made in the district, at localities known as Mine à Robina, Mine à Joe, American Mines, and at other places. The Spanish government — for the territory was then under Spanish rule — allowed the miners to work on public land free of any tax, and a period of considerable prosperity ensued.

It is impossible to arrive at any trustworthy estimate of

[1] Burton, or Breton, was an old French soldier who served at Braddock's defeat, at the siege of Louisbourg, and at other celebrated battles. He was a hunter in Missouri, and discovered the mine during one of his hunting expeditions. He is said to have lived to the age of 109 years.

[2] Schoolcraft says there were three shot-towers on the cliff near Herculaneum at the time of his visit, in 1819. The lead was melted on the top of a precipitous cliff, and dropped to the bank of the river below, thus ingeniously saving the cost of erecting a tower.

the production of the Missouri mines under French and Spanish rule. Mills estimates the production of Mine La Motte, from 1723 to 1804, at 8000 tons.[1] The production during French rule, except at Mine La Motte, was probably small. During Spanish occupation the product largely increased; Austin, however, mentions but four mines being operated in 1804.

In 1803, the territory, or province, of Louisiana was purchased by the United States, and most of the French and Spanish concessions, when they had been continuously occupied, were confirmed by a commission.

Bradbury, writing in 1810, says, "The ore is found in detached lumps in the clay, which is colored red by decomposed iron oxide." He says the workmen had no other implements than a pick and a wooden shovel. When they came to the rock they abandoned the pit and began a new digging. The workmen were mostly Creole French. As soon as a district was discovered in which the ore was abundant enough to warrant the erection of a furnace, a name was given to it. Mine au Shibboleth was discovered while Bradbury was in the country, and 2000 tons of lead, he says, were produced from this mine in one summer.[2] Brackenridge estimated the annual production, in 1810, at about 760 tons.[3] Schoolcraft visited the district in 1819, and made some valuable investigations and researches respecting the character and extent of the mineral deposits, the early history of the country, and the discovery of the lead fields. He comments upon the crude methods employed, and says: "There are not over four or five regular shafts, out of about forty mines; there is not an engine, either horse, steam, or water-power, for re-

[1] James E. Mills, B.S., Geological Report on the Mine La Motte Estate, New York, 1877.

[2] Bradbury, Travels in the Interior of America, etc., p. 250 *et seq.*

[3] Brackenridge, Views of Louisiana, p. 154.

moving water from the mines, several of which have been abandoned on this account with the richest prospects in view."[1] The annual production at this time is estimated by Schoolcraft, in the forty-six mines then being operated (every digging was called a mine), at 1,500 tons, giving employment to 1,100 men. Mine Shibboleth, in 1811, produced 1,600 tons; and from 1798 to 1816, Mine à Burton and the Potosi diggings yielded together 4,800 tons.[2]

The period from 1830 to 1845 was probably the most prosperous in the early history of this district, but it is impossible to find any records of a trustworthy nature upon which to base an estimate of the output.

In 1790, Mine La Motte was acquired by purchase by Jean Baptiste Pratte, Jean Baptiste St. Gemme Beauvais, François Vallé, and Jean Baptiste Vallé. Work was prosecuted at this mine by many individuals at various times, until 1839, when the La Motte Mining Company was formed for working the deposits upon an extensive scale. The production from 1804 to 1819 is estimated by Mills at 4,000 tons; from 1820 to 1833, at 7,300 tons; from 1834 to 1837, at 1,500 tons.[3]

Previous to 1838, the lead carbonate, cerussite, called by the miners "dry bone," was rejected by them as valueless, and it accumulated in great heaps. In that year a Prussian named Hagen arrived at the mine, and shortly after entered into partnership with Vallé, who was then working it. Hagen knew the value of the "dry bone," and erected furnaces for its reduction. The result of the utilization of the cerussite was a largely increased production, amounting to upwards of 10,000 tons during the period from 1838 to 1850. From 1851 to 1861, operations were checked owing to litigation, and the output is estimated at no more than 1,400 tons during this period. In 1861 the

[1] Schoolcraft, Views of the Lead Mines, etc., p. 22. [2] Ibid. p. 116 *et seq.*
[3] Mills, Geological Report of Mine La Motte.

furnaces were destroyed by the United States troops, to prevent the utilization of the deposits by the Confederates.[1] They were rebuilt soon afterwards, and work was continued on a small scale until 1869, when the property passed into the hands of the Mine La Motte Company, to be transferred to the La Motte Lead Company, in 1870, and finally to Mr. Rowland Hazard, of Providence, in 1875. The immense property, consisting of nearly 24,000 acres of mineral lands in one body, and about 10,000 acres of pine lands in the immediate neighborhood of the mineral lands, is owned entirely by Mr. Hazard, and mining and smelting operations, inaugurated some years since upon a scientific and economical basis, are being successfully conducted by his able manager and his assistants.

From 1845, mining operations in Missouri, which had previously been conducted almost exclusively in the surface diggings, owing to the exhaustion of the ore began to decline. Until 1867 this decline steadily continued, but about that time the deposit in St. François County, which had been worked in the old way for many years, were explored to a deeper level, and a stratum of limestone, in which lead ore is disseminated, was discovered at about one hundred feet below the surface. The St. Joseph Lead Company was formed, and proper works were erected for dressing the ore, and improved methods adopted for smelting and refining. The introduction of the diamond drill rendered it possible to examine the strata many hundred feet below the surface, at a moderate cost. The result in this locality has been the establishment of the fact of the occurrence at intervals, up to four hundred feet below the surface, of several strata of limestone, bearing disseminated through it lead ore in paying quantities.

Adjoining the property of the St. Joseph Company are

[1] Mills, Geological Report on Mine La Motte.

the lead deposits owned for more than a hundred years by the Pratte family, and for a considerable portion of this period exploited in the old way. In 1874, Mr. Firmin Desloge developed the fact of the existence of the lead-bearing strata underlying this property. Desloge organized the Desloge Lead Company, bought the property, and began the erection of an extensive plant for the treatment of the ore by scientific and modern methods. The Desloge Company operated their mine successfully for ten years, when their ore-dressing works were destroyed by fire. A consolidation was then effected, or rather the St. Joseph Company bought out the property and remaining plant of the Desloge Company, increased their capital to $1,500,000, and since that period have worked the mines of both companies.

The early smelters obtained the metal from the disseminated lead ore by first burning it upon a log heap, then pulverizing it by pounding with a bucking-iron; the ore was then imperfectly washed by hand jigs, and finally smelted in the old log furnace. The methods now in use at the St. Joseph Company's works represent the refinement of scientific ingenuity and economy. The ore is mined and hoisted to the mouth of the shaft, which immediately adjoins the ore-dressing mill. From the shaft the ore is transported, in cars carrying some 1,500 pounds, to the dumps before which are conveniently arranged some twelve or fifteen powerful crushers, into which the rock bearing the ore is shovelled by men; and here manual labor in the operation ends, for once caught in the irresistible jaws of the crusher, the ore moves by gravity until reduced to the proper degree of fineness, when, mixed with water, it is pumped by powerful centrifugal pumps to the jigs and slime-dressing tables, where the complete separation of the ore from the limestone matrix is effected. The débris, or *chat*, to use the miners' term, is pumped into cars

which stand conveniently at the rear of the building; the water quickly drains off, and the chat is hauled away in train-loads by one of the five locomotives which are in constant use at the works, and is utilized in building roads or in filling up ravines. The ore is deposited in the same manner in other cars, which are hauled to the calcining furnaces, whence, after treatment, it goes to the blast furnaces, where the impurities in the ore are eliminated; then it is passed through the refining furnace, from which it is run into moulds and is ready for market.

The works of this company are among the largest and most complete in the world, and evidence in the highest degree the wise management of its president, and the ingenuity and skill of its superintendent. Fully one thousand tons of the lead-bearing limestone is daily mined, brought to the surface, crushed, the ore perfectly separated, and the metal liberated, producing upwards of twelve thousand tons of metallic lead per annum. The company owns many thousand acres of land, upon which they have built their thriving and picturesque town of Bonne Terre,[1] with its six thousand inhabitants, its free hospital, free library and reading room, club room, and eight churches. The company also owns and operates, upon its own domain, a railroad more than thirteen miles long, which connects its works with the St. Louis, Iron Mountain, and Southern Railway, at Summit, sixty-three miles from St. Louis.

The ores of Mine La Motte and St. Joseph contain nickel and cobalt in notable quantities, and in this they differ from the ores found in the surface diggings. The nickel is carefully preserved in the treatment of the ore, and is finally concentrated, and in the form of matte or speiss is shipped to Europe, for further treatment and

[1] *Bonne terre* is the name given by the old French miners to the loose gravelly soil lying above or in the neighborhood of ore bodies.

purification in the metallurgical establishments of England and of Germany.

The principal production in southeast Missouri, for ten years or more, has been from the furnaces of Mine La Motte, St. Joseph, and Desloge. The utilization of the disseminated ore marks an era in the mining industry of the State. There is every indication of the practically inexhaustible nature of the deposits at St. Joseph and at Mine La Motte. Mills estimates that no less than fifty-five thousand tons of metallic lead have been produced at Mine La Motte from the date of its discovery up to 1876.[1] It is known that similar deposits exist in other localities in the mineral region of southeast Missouri, and it is believed there are many deposits yet undiscovered. The successful operations at the St. Joseph Mine have stimulated prospecting, and many new discoveries have been announced. At Doe Run, in St. François County, explorations have demonstrated the occurrence of a body of ore, richer than and quite as extensive as at Bonne Terre, and a plant is now being erected to exploit it. It is confidently believed that the production in this district will be materially increased in the near future, and that Missouri will occupy a more prominent position as one of the great lead producing districts of the world.

The lead deposits of southwest Missouri are commonly thought to have been discovered about the year 1848; but Brackenridge, writing in 1810, says that he has been informed by hunters that lead ore in great abundance exists in the country watered by White River, many of whose numerous branches rise in or flow through the southwest counties of the State.[2] Schoolcraft, in 1818, journeyed from Potosi in a southwest direction through the State, and reached a point in Stone County, near Jasper, where

[1] Mills, Geological Report of Mine La Motte.

[2] Brackenridge, Views of Louisiana, p. 146.

he found lead ore in abundance, and smelted it to furnish bullets for his guns.[1]

In 1848, galena was found near the home of William Tingle, situated in Jasper County, about two miles from the site of the town of Joplin. Tingle prospected in the neighborhood, and soon proved that the loose float mineral surely indicated the presence of important deposits of lead ore of remarkable purity; and for some years ore was raised in a small way, and either smelted on the spot in primitive furnaces, or sold to the Granby smelters, in the adjoining county. In 1850, the lead deposits in Newton County were discovered, on Cedar Creek, near what is known as the Old Mosely Mine. It is undoubtedly true that many persons were aware, in 1850, of the existence of bodies of galena in Newton and Jasper counties, and in that year, and in 1851, considerable superficial prospecting was done in the district, resulting in the discovery of many bodies of ore lying very near the surface. Smelting was begun in 1852, when the ore was reduced in simple log furnaces, and the lead reached a market by wagons to Fort Smith on the Arkansas River, thence by steamers to New Orleans, and by sail to New York or Boston. The absence of cheap transportation, and the low price of lead, rendered the work unprofitable, and operations were limited and desultory until 1856, when Messrs. Peter E. Blow and Ferdinand Kennett visited the district, assured themselves of the richness and extent of the deposits, and effected a lease of the lands from the South Pacific Railway Company, to whom they had been granted by the government. The next year, these enterprising men established the town of Granby, erected furnaces of large capacity and of improved design, and began to develop the mines. They worked their furnaces to their full capacity until the

[1] Schoolcraft, Journal of a Tour into the Interior of Missouri and Arkansaw (London, 1821), p. 55 *et seq.*

breaking out of the Civil War. The Confederate troops, on their advance into the State in 1861, seized large quantities of lead belonging to the smelters; and during the war the furnaces were worked by both the Federal and the Confederate troops, as the vicissitudes of the war gave them possession. At the close of the war, in 1865, the mines were once more leased to the successors of Blow and Kennett, the Granby Mining and Smelting Company; the shafts were cleared out, the furnaces repaired, new ones erected, and operations were pushed with great vigor. In 1874, the principal ore bodies on the lands controlled by the Granby Company showed signs of exhaustion, and the product of this company since that time has materially declined.

Start The lead fields in Jasper County did not attract general attention until 1870, when some enterprising men began vigorously exploiting the deposits, and the little hamlet of Joplin became within a few months a thriving and populous town, and the centre of one of the important lead-producing districts in the United States.

The deposits in this, and the neighboring county of Newton, occur in horizontal leads, or openings, in regular ranges running from northwest to southeast. The country is prairie and timber, and the ore occurs everywhere in the clay, in loose cherty beds, and in the hard rock; evidences exist throughout the whole district, in float mineral, or pieces scattered over the surface or just below it, in ravines where it has been uncovered by the action of running water, and in the beds of streams. It has been said that a shaft cannot be sunk to a depth of ten feet in any part of the district without striking ore. The mining, or digging, has been superficial; shafts over a hundred feet in depth are exceptional, but, according to Mr. Kingston, superintendent of the Granby Company, one shaft has been sunk to the depth of two hundred and twenty-five

feet, and the indications were not at all discouraging.[1] Broadhead estimates the production of the Granby mines, from the beginning of mining to the end of 1873, at 27,000 tons of lead; and of the Joplin district, from 1871 to 1873, inclusive, at 17,500 tons.[2] Mr. E. A. Caswell, of New York, gives the following as the production of the southwest Missouri mines in 1873, and following years:—

Year.	Tons.	Year.	Tons.
1873	12,280	1880	15,780
1874	13,830	1881	15,500
1875	13,525	1882	11,670
1876	14,634	1883	7,645
1877	17,765	1884	2,665
1878	13,650	1885	6,070
1879	13,928	1886	6,482

The argentiferous lead deposits of the Great West first attracted general attention about the year 1864, when the Eureka district was organized. A company was formed in New York to exploit these deposits; but the claims, though very rich, were soon abandoned on account of inaccessibility to a market, and the district was uninhabited for some years.[3]

Smelting was successfully conducted at Helena, Montana, and at Orena, Nevada, in 1866 and 1867, but the bullion was cupelled upon the spot, the absence of cheap transportation rendering the lead in that wild country valueless. The completion of the Union Pacific Railway, in 1869, brought these, and other valuable deposits, within

[1] The facts relating to the Granby and Joplin lead districts have been principally supplied by Mr. John Kingston, superintendent Granby Mining and Smelting Company, of Granby, Mo., and Judge O. H. Picher of Joplin, Mo., whose courtesy is here acknowledged.

[2] Broadhead, G. C., Report of the Geological Survey of Missouri for 1873–74 (Jefferson City, Mo., 1874), p. 502.

[3] Curtis, J. S., Silver Lead Deposits of Eureka, Nevada (Washington, 1884), p. 3.

reach of a market, and the development of the vast silver-lead deposits of Nevada and Colorado was fairly entered upon.[1] In this year, mining operations were reopened at Eureka, and in 1870 the Eureka Company was formed, extensive furnaces erected, and from this date to 1885 it is estimated that nearly 250,000 tons of lead were produced.[2] Prior to 1873, special records of the production of each mining district in the far West are wanting, though the statistics of the total production of the States and Territories in the Rocky Mountain region is given in the Reports of the United States Geological Survey. The production of the Eureka district is estimated as follows: —

Year.	Tons.	Year.	Tons.
1877	19,724	1882	8,590
1878	31,063	1883	6,000
1879	22,805	1884	4,000
1880	16,650	1885	3,500
1881	12,826	1886	4,500

The ores of this district have been treated at the furnaces of the Eureka Company, the base bullion being refined at the works of the Richmond Company, or shipped to Newark, N. J., or to San Francisco, for treatment. The lead produced by the Richmond Company has generally been marketed in New York.[3]

The lead deposits of Utah were known to the Mormons soon after their settlement of the valley of Salt Lake, but at first the only mining and smelting done was to supply the wants of the territory, and no attempt was made to recover the silver. Later the ores were sent East for

[1] Mineral Resources of the United States (Washington, 1883, article by O. H. Hahn), p. 324.

[2] Curtis, Silver Lead Deposits of Eureka, p. 175.

[3] Mineral Resources of the United States, — United States Geological Survey (Washington, 1883), p. 309. Mineral Resources of the United States, — United States Geological Survey (Washington, 1885), p. 418.

reduction, but in 1870, local smelters and refineries were erected, and since that time operations have been actively prosecuted.[1] The production since 1870 is estimated as follows: —

Year.	Tons.	Year.	Tons.
1871	5,000	1879	14,000
1872	8,000	1880	15,000
1873	15,000	1881	24,000
1874	20,000	1882	30,000
1875	19,000	1883	29,000
1876	25,000	1884	28,000
1877	27,000	1885	29,160
1878	21,000	1886	24,332

It is said that in 1861 some gulch miners, while hunting in Colorado, ran out of bullets, and finding a vein of lead ore, smelted some of the outcroppings to supply the deficiency. Happening, a few years later, to be in Nevada, they were struck with the resemblance of the rich argentiferous lead ores of that district to the lead vein in Colorado from which they had made bullets on their hunting expedition. They immediately took measures to locate the vein of lead ore in Colorado, but the remoteness from market prevented active operations at the time, and nothing was done for many years.

The production of lead in Colorado prior to 1878 was quite unimportant, but from that time the increase is phenomenal. In the publications of the United States Geological Survey, the production in the Territory is given as follows: —

Year.	Tons.	Year.	Tons.
1873	56	1880	35,674
1874	312	1881	40,547
1875	818	1882	55,000
1876	667	1883	70,557
1877	897	1884	63,165
1878	6,369	1885 (estimated)	55,000
1879	23,674	1886	48,460

[1] Mineral Resources of the United States, 1883 and 1884, — Report United States Geological Survey (Washington, 1885), p. 416.

The great increase since 1878 is principally due to the discovery and development of the wonderful carbonate deposits near Leadville. The production of lead in this district is estimated as follows: —

Year.	Tons.	Year.	Tons.
1877 . .	175	1882 . .	39,864
1878 . .	2,324	1883 . .	36,870
1879 . .	17,650	1884 . .	35,296
1880 . .	33,551	1885 . .	19,127
1881 . .	38,101	1886 . .	25,962

The great falling off in the output in 1885 may be traced to the exhaustion of some of the mines; but new discoveries have been made, and old shafts are being carried deeper, a draining tunnel is being constructed, and it is believed that the output will largely increase.

Extensive lead deposits have lately been discovered at Aspen, and at other points near or tributary to Leadville, and the completion of projected railways will bring to the Leadville smelters an abundant supply of ore.

During the past few years the output of lead in Montana has steadily increased, and now that the Northern Pacific Railway affords an outlet, this Territory promises to become an important source of supply.

Considerable activity has lately been developed in the mining of lead ores in Idaho; numerous important deposits are known to exist, and the output of 1882 is estimated to have yielded 5,000 tons of lead. The increase in the two succeeding years did not equal expectations, but in 1884 the production is estimated at 7,500 tons.

New Mexico has shown a decided increase in the production of lead during the past three years. The deposits of ore in the Territory are known to be large and exceptionally rich in lead, though carrying a smaller amount of silver than the ores of other western districts. The production in 1883 has been estimated at 2,400 tons, increasing

to 5,000 tons in 1884, 9,000 tons in 1885, and 9,800 tons in 1886.

The shipment of ores and concentrates from one State or Territory to another, during the past three years, renders it impossible now to arrive at trustworthy estimates of the production of each State or Territory; and the attempt to compile such statistics has been abandoned, since 1884, by the Geological Survey. This Bureau has contented itself with giving the total production of the United States, divided into the quantities derived from argentiferous and non-argentiferous ores. This division is possible owing to the fact that the non-argentiferous ores are principally produced in Missouri, Kansas, Illinois, and Wisconsin; but these data are not perhaps infallible, as the smelting works at St. Louis, and perhaps at Kansas City, usually working argentiferous lead ores and bullion, have purchased considerable quantities of Missouri and Kansas ores to mix with dry ores obtained from Mexico and elsewhere.

By reference to the report of the Geological Survey it will be seen that the lead production of the United States culminated in 1883, when the total output reached 143,957 tons. This production was in excess of the demands of the country, and a period of depression ensued, during which the value of the metal was abnormally low. To add to the unsatisfactory state of the lead-mining industry at this time, silver declined largely and steadily, and many mines were abandoned and prospecting operations were checked. The result is shown in the decreased output, which fell to 139,897 tons in 1884, and to 129,412 tons in 1885. During the latter part of that year an unusually heavy demand for consumption cleared out the surplus stocks, and a sharp advance in the price of lead occurred. Silver continued to decline during the early part of 1886, but the advance in the price of lead stimulated mining enterprises; and

the extension of existing railways, and the building and projection of new ones, brought new territory and new deposits within reach of a market, resulting in the increase of the production in 1886 to 135,629 tons. A revival in mining interests developed in 1886, and in some sections reached proportions almost unexampled. The result is the opening up of many old and abandoned claims, and a vigorous prospecting of new territory. While the disappointments must far outweigh the successes, the results must certainly lead to a more thorough prospecting of the mining region, to a more successful exploitation of some old mines, and to an increased production in 1887. Should the present anticipations be realized, it is not improbable that the output for 1887 will reach the amount produced in the year of the greatest prosperity of the American lead-mining industry.

There are extensive deposits of argentiferous galena in Mexico; but the inaccessibility of some of the mining districts, and the disturbed condition of others, has heretofore impeded operations, and the production of lead in this country has been comparatively insignificant. Lead is produced in sufficient quantities to supply the meagre wants of the inhabitants, and for metallurgical purposes. Lead ore is exported in limited but increasing quantities to the United States, and a small amount of argentiferous lead is exported to Great Britain. The completion of several lines of railway, and the projection of others, has drawn attention to this country as another field for American mining enterprise.

The Mexicans, before the Conquest, were familiar with gold, silver, copper, tin, and lead, — the latter obtained from their mines at Tasco. Their mining operations were extensive, notwithstanding their only implements were of bronze, made from their own tin and copper; they had ample stores of iron ore, but were unacquainted with

methods for reducing it. If they were able to work their mines below the water level, like some of their Spanish successors, who were too poor to erect pumping-engines, they must have relied upon buckets of hide to remove that obstacle.[1]

The Spaniards opened mines in Mexico as early as 1526, and worked them until 1810. The period of greatest activity, however, was subsequent to 1700. The war for independence occasioned a partial or complete cessation of mining, and many mines were abandoned. After the expulsion of the Spaniards English capitalists became interested in Mexican mines, and for some years persisted, at great loss, in clearing out the old mines and erecting new and improved machinery; but the absence of cheap transportation proved a barrier to profitable work. For some years the disturbed political condition of Mexico, and the raids of the Apaches in the important mining States of Chihuahua, Sonora, and Durango, depressed mining interests and discouraged the introduction of foreign capital and skill. Now, however, the completion of railways, the subjugation of the Apaches, the presence of foreign capital, and the introduction of improved machinery, has stimulated mining interests, and we may look for a period of prosperity which will equal the best days of Spanish occupation.[2]

While the attention of capital interested in Mexican mining has heretofore been directed almost exclusively to the production of silver, the extension of the railway system will, in the near future, give additional value to the argentiferous lead ores, by making the lead an important factor in the metallurgy of this interesting country. Al-

[1] W. H. Prescott, History of the Conquest of Mexico (Philadelphia, 1863, 3 vols.), vol. i. p. 38. See also H. H. Bancroft, The Native Races of the Pacific States, vol. ii. p. 473.

[2] Charles B. Dahlgren, Historic Mines of Mexico (New York, 1883), p. 20 *et seq.*

though but little information exists of the extent of the lead deposits, enough is known to warrant the statement that they are abundant and valuable.

In the States of Guanaxuato and Zacatecas there are important deposits of argentiferous galenas; in the district of Mazapil, in the latter State, the mines discovered in 1530 continue to be profitably worked, although the raids of the Apaches occasioned an almost entire abandonment of them for a considerable period. In Sonora and Chihuahua the ores in some mines resemble those of Leadville, Colorado, and Eureka, Nevada. In the district of Santa Barbara, and in the districts of Cuencame and Mapimi in Durango, argentiferous lead ores exist. In Coahuila, the argentiferous lead deposits have been worked by the Mexicans for years. In Jalisco, Michoacan, and in other States mentioned by Dahlgren, there are well defined lead deposits. The mines of Tasco were the first worked by the Spaniards. In Hidalgo, in the district of Zimapan, large quantities of lead ore have been taken out by the owners.[1] The San Antonio and other mines in the neighborhood of Monterey are worked by Americans, but the output is unimportant.[2]

Were it not for the duty on lead ores the deposits of Mexico would be actively exploited, and shipped in large quantities to the smelters in the United States. The absence of fuel in the neighborhood of some of the more important mines makes smelting expensive, but labor is much cheaper than in the United States, and when the deposits in the Rocky Mountain district are exhausted, our smelters will look to Mexico for supplies.

The evidence afforded by old Spanish writers shows conclusively that the native Peruvians, before the conquest,

[1] Dahlgren, Historic Mines of Mexico, p. 61 *et seq.*

[2] R. C. Campbell, in United States Consular Report No. 67 (Washington, 1886), p. 493.

were acquainted with lead in its metallic state. Modern explorers have discovered, among the spoils of ancient Peruvian graves, articles of lead and of bronze, — thus corroborating the statements of the Spanish writers, and proving that the South American aborigines were much more advanced in civilization than the tribes inhabiting the district now included in the United States, and were familiar with the process of smelting and other metallurgical operations. According to Tschudi, the Cordillera in the neighborhood of Tauli is exceedingly rich in argentiferous lead ore, and more than eight hundred shafts have been sunk; but owing to the scarcity or high cost of labor and fuel (wood is not to be had, and the smelter relies entirely upon the dried dung of sheep, llamas, and huanacos), the work has been unprofitable. The Portuguese formerly worked the deposits in this district very extensively, but were driven from the country, and their works have been abandoned.[1]

There is no doubt of the great mineral wealth of South America. Lead abounds in the mountains of Peru, Bolivia, Chili, in Uraguay, and in other States; but owing to the absence of transportation facilities and the unsettled state of society, little exploration has been attempted. When the political troubles are settled, and railways are constructed into the elevated districts, that continent will doubtless become an important centre for the distribution of metals to the civilized world.

[1] Dr. J. J. Von Tschudi, Travels in Peru during the years 1838–42, translated by Thomasina Ross (New York, 1852), pp. 198, 200.

CHAPTER VI.

SMELTING AND REFINING.

LEAD is rarely found pure in nature, and when it occurs in this form it is generally in thin plates or in small pellets, and is much like commercial lead in appearance. The principal ores and those from which the lead of commerce is almost exclusively derived, are the sulphide and the carbonate; the other ores are rarely found in considerable quantities, and are consequently of little commercial importance, though many are of more than ordinary interest to the mineralogist.

Native lead sulphide, or "galena," the name by which it is commonly known, is the most important, and the most widely distributed ore of lead. The origin of the name "galena" is doubtful, and much confusion existed in ancient times in its use. Pliny applies it to "the vein of lead that is mostly found running near the veins of silver ore;"[1] he also applies the name to "litharge," one of the products formed in the refining of argentiferous lead by the process of cupellation;[2] he refers to it again as "a mineral compounded of silver and lead;" and in another chapter he says it is the same as molybdena.[3]

Galena generally contains, invisibly associated with it, gold, silver, antimony, zinc, copper, iron, and occasionally nickel and cobalt; and it frequently has visibly associated

[1] Pliny, Natural History, book xxxiii. chap. xxxi.
[2] Ibid., book xxxiv. chap. xlvii. [3] Ibid., book xxxiv. chap. lii.

with it zinc blende, iron and copper pyrites, barium sulphate, etc. It is an interesting fact that gold and silver are always associated with lead in galena, even the purest ores containing at least a trace of the noble metals. The purest galena contains about 86 per cent of lead, and 14 per cent of sulphur; it is found in nearly every geological formation, and in nearly every country on the globe; it is one of the most important sources of silver,—the ores carrying this precious metal in economical quantities being generally found in the older and metamorphosed rocks. Galena has been employed in some countries, when very pure, under the name of alquifoux or potters' ore, for glazing coarse pottery, and earthenware; and it is exported from countries bordering upon the Mediterranean to Egypt, where it has been used for ages as a remedy for ophthalmia.

Cerussite, or native lead carbonate, is also a widely distributed ore, though it is seldom found in large quantities, except in the region in and about the Rocky Mountains, in Prussia near Düren, in Bavaria, near Cartagena in Spain, and if recent reports are verified, in the Broken Hill district in New South Wales. This mineral was not considered as of much commercial importance until the immense deposits in Nevada and Colorado were discovered. Cerussite is commonly associated with galena, and is thought to be formed by the action of atmospheric oxygen, or of oxygen dissolved in water, combined probably with an aqueous solution of calcium carbonate, upon galena.

Some of the other ores of lead are the sulphate, found in many parts of Europe and America, the chromate, molybdate, and many other minerals, more or less common, formed of various combinations of lead with sulphur, arsenic, copper, etc., none of which are of much commercial importance, their occurrence being usually in small quantities.

The ores of lead do not always form true veins, but often occur in irregular pockets or caves, and gashes in the rocks, frequently very rich in certain strata, and thinning or giving out entirely upon entering another. In the lead fields of Missouri, Illinois, and Wisconsin, masses of ore are found in the clay, having been washed out from the decomposing rocks in which it was originally deposited and left irregularly distributed through the soil.[1]

The earliest writers refer to gold, silver, copper, lead, and iron in such a manner as to make it evident that the simpler processes of metallurgy were known at a very remote period. Whence this knowledge originated, and what were the methods adopted, we have no means of determining. Ancient writers refer to furnaces for smelting purposes, but give no explanation of their construction. The first distinct description of a furnace for smelting metals appears in the writings of Geber, an author of the eighth century.

The Chaldeans, Egyptians, and the people of the Orient, were acquainted with metallurgical processes in their simple forms, and imparted this knowledge to the Hebrews, Greeks, and Romans. It has been suggested that the absence of intelligible descriptions of ancient metallurgical methods may be explained by the fact that the Romans were obliged to trust important mining and metallurgical works to foreigners, — prisoners-of-war, and slaves, — who, to render themselves of more consequence, threw a veil of mystery about their operations.[2] But a sufficient explanation may perhaps be found, if we consider that metallurgical operations, such as smelting and refining, were conducted in ancient times in the mountains near the mines, in districts comparatively inaccessible to the writers in whose works we search for descriptions of the

[1] See Whitney, Metallic Wealth of the United States, p. 412.

[2] Leger, Les Travaux Publics, etc., p. 712.

methods employed, so that they were obliged to depend upon the statements of others for a knowledge of these technicalities.

The ancients of course were ignorant of modern theories, and the meagre descriptions we have of their methods are frequently cumbered with absurd empirical recipes; but they successfully conducted metallurgical processes, many of which have some claim to refinement; and if we eliminate the absurdities from the descriptions of their methods, we find that their processes differ but little from those in use to-day, and that these differences are generally only such as are consequent upon the employment in modern times of more efficient and powerful apparatus.[1]

The smelting of pure galena is a comparatively simple metallurgical operation, and the process has probably been independently discovered by primitive peoples wherever the ore occurred. Lamborn says that the early settler in Missouri learned to procure the lead for his bullets by building a fire in the hollow of a fallen tree or in an old stump, and throwing upon it pieces of galena which he had found upon the ground; he recovered the lead from the ashes.[2] The furnaces of primitive man were modelled upon this simple plan.

As stated above, the purer galena is composed of lead and sulphur, with small quantities, often mere traces, of other metals. Were the ore a combination of lead and oxygen, then mixing with charcoal and heating in a furnace would liberate the metal; but a compound of lead and sulphur, when subjected to a moderate heat with access of air, is partially transformed into lead sulphate and lead oxide, which reacting, when the temperature is raised, upon the unchanged galena, results in the production of metallic lead, while the sulphur and oxygen are liberated

[1] Leger, Les Travaux Publics, etc., p. 712.
[2] Lamborn, The Metallurgy of Lead and Silver, p. 132.

and escape as sulphurous acid gas. The extemporized furnace of the Missouri hunter did not freely permit the reaction just described, and while it enabled him to secure a portion of the metallic lead contained in the ore, it failed to reduce all; so that primitive smelting was wasteful in the extreme, and as shown elsewhere, the slag and ash-heaps left by the early metallurgists have been reworked in modern times with great profit.

In the absence of written accounts of the ancient methods of smelting, modern investigators have been obliged to study the location and surroundings of old slag heaps, which are found in great numbers and often of prodigious size in the neighborhood of lead deposits anciently worked, and to deduce therefrom the methods employed in ancient times.

According to Leger, the Romans reduced galena in "fourneaux à manche," — the simplest form of ancient furnaces. They were small and were used in Spain, England, Tuscany, and Greece, for the reduction of the ores of copper, iron, tin, and lead.[1] This author also refers to the fact that during the time of the Empire the Romans established Imperial foundries, where the ores of the mines of conquered countries, and the "Imperial tenth" paid by private exploiters were treated. It has been suggested that the pigs of lead bearing the names of Roman emperors, and found in modern times in England and in France, were the property of the State, and were smelted at the Imperial foundries.[2] Smelting in the Urals, by metallurgists of the second century B.C., was conducted in brick furnaces not over two feet high and three feet wide. Gmelin is said to have found many hundreds of such furnaces in eastern Siberia. They were furnished with a hole for the introduction of the nose of the bellows, and with another on the opposite side for the liberation of the metal.

[1] Leger, Les Travaux Publics, p. 715. [2] Ibid., p. 712.

Great heaps of débris attest the extent of the ancient operations.[1]

The ancient Briton, before the Conquest, dug a pit which he filled with broken ore and fuel; upon firing the mass the lead, as it was melted, ran out of the pit into another and smaller depression in the ground prepared to receive it, and connected with the principal pit by a narrow channel.[2] The Indians of the upper Mississippi smelted the pure ores of that region in the following manner: large logs were placed upon the ground, and smaller logs and pieces of split wood were piled around them; the ore was then heaped upon the pile and the mass fired in the evening; the next morning, the fuel being exhausted, the ashes were raked and the melted lead recovered. Sometimes the log heaps were built over a small pit dug in the ground to receive the molten metal. Mention is made elsewhere of the discovery of cakes of lead in England which were evidently products of similar furnaces.

In these descriptions of primitive smelting no reference is made to methods for urging the fires. A moderate blast of air is certainly necessary to the successful reduction of a considerable portion of the ore. It is probable that in the methods just described the pits and ore heaps were placed upon sloping ground, — the side of a hill, — to take advantage of natural air-currents.

The ancient Peruvians, before the Spanish conquest, smelted their argentiferous ores by heating them in earthen pots. Knowing no method of creating an artificial blast, they carried them to the hills, and placed them on that side of the hill towards which the wind was blowing. They regulated the force of the blast by carrying them higher or lower according to the strength of the wind.[3]

[1] Phillips and Darlington, Records of Mining and Metallurgy, p. 17.

[2] Pennant, A Tour in Wales, vol. i. p. 61.

[3] Royal Commentaries of Peru, Garcilaso de la Vega, translated by Sir Paul Ricaut (London, 1688), p. 346.

Ancient smelting-places have been found in England, called "boles," situated generally upon rising ground, usually upon that side of the hill facing the west, the direction of the prevailing winds. Sometimes these boles were situated in a small ravine or depression in the hill, or pits were excavated as already described; occasionally these smelting places consisted simply of heaps of stones placed around a fire.[1] Camden refers to this method of smelting in describing the lead deposits of Derbyshire. He says: "For in these mountains fertile lead-stones are daily digged up in great aboundance, which upon the hill-tops lying open to the west winde, neere unto *Creach* and *Workes-Worth* (which hereupon took the name of the lead-workes) when the westerne winde beginnes to blow (which winde of all others they have by experience found to hold longest) they melt with mighty great fires of wood into lead, in troughes or trenches which they digge of purpose for it to runne into, and so make it up into *Sowes*."[2] According to tradition the earliest mode of smelting tin in Cornwall consisted simply of making a pile of sticks and ore in the open; when fired the molten metal flowed from the bottom.[3] A furnace used by the Indians of the upper Mississippi is described by a recent writer as follows: "A hole was dug in the face of a piece of sloping ground, about two feet deep and the same in width at the top, with sloping sides assuming the shape of a mill-hopper; this pit was lined with flat stones and at the bottom, which was eight or nine inches square, narrow stones were laid across like grate bars. A channel was dug from the sloping ground inward to the bottom of the pit or hopper, a foot in width and height, and was filled with dry

[1] Percy, The Metallurgy of Lead, etc., p. 216.

[2] Camden, Britain, etc., p. 556.

[3] John Phillips, Thoughts on Ancient Metallurgy,—Archæological Journal of Archæological Institute of Great Britain and Ireland, vol. xvi.

wood or brush; the hopper being filled with ore and the fuel ignited, the melted lead fell through the stone grate bars and flowed through the channel into a rude mould arranged at the entrance to receive it; when cooled, the mould of lead, which was called a "plat," and weighed about seventy pounds, was ready to be sold to the traders.[1] The work, we are told, was principally undertaken by the squaws, — a statement we can readily accept, as being quite in accordance with the well-known character of the North American Indians.

The French smelters of southeast Missouri probably borrowed their methods of smelting from the Indians. They prepared heaps of logs, upon which they piled the ore; near the foot of the heap they made an excavation in the ground, of the shape, but somewhat larger than, a brick; they then stuck a small stick upright in the centre of this mould. When the lead was melted and began to run, it was guided by a little channel, prepared beforehand, into the mould, and when cool a pig of lead with a hole through it had been formed. As these pigs of lead were to be transported to the river, some thirty miles away, a rawhide rope was run through the hole; the pig could then be swung over the shoulder of a man, or the back of a horse.

The log furnace of the early smelter of the Missouri and the upper Mississippi mines was but little better than the furnaces of the squaws, except that its construction was somewhat more substantial. It was built on sloping ground, and consisted of a hearth of stone, surrounded on the front and two sides by a stone wall, seven feet high in front. The top and the rear end were left open; in

[1] Harper's Magazine, vol. xxxii. p. 682. Bradbury describes the method of smelting by the squaws of the "Saukee and Fox" nations of Indians in much the same manner. He says the plats of lead were bought by the traders, who remelted it and cast it in pigs before sending it to market. — Travels in the Interior of America, p. 255.

front an arch or opening was made, forming the eye of the furnace, and in front of this a pit was dug in the ground, to receive the molten metal. Large logs were rolled in at the back and made to rest upon ledges formed inside, to raise them from the hearth and to give a draught; these logs filled the entire width of the furnace. Small split logs were then set up around on the two sides and the front, and the ore was then piled on until the furnace was full. Finally, the mass was covered with logs and fuel until the ore was completely surrounded. A gentle heat was started, which was raised very gradually; after twelve hours the heat was increased and continued for twelve hours more, — twenty-four hours being required for each smelting. The ore yielded about fifty per cent of metallic lead. A considerable quantity of the ore was not desulphurized, and fell between the logs into the ashes, forming a kind of slag, which was called "lead ashes;" this was rich in lead, and was frequently treated in a furnace of a peculiar construction, called an "ash furnace." This also was built upon sloping ground and was provided with a sloping flue, about ten feet long, through which the lead ashes, after washing and cleaning, was charged with a quantity of silicious sand or other material to form a flux. The ash-furnace recovered from ten to twenty per cent of lead.[1]

The slag, or lead ashes, was largely thrown aside by early smelters as refuse, but in later times modern methods have enabled their successors to recover vast quantities of metal from these old heaps. According to Hunt, in ten years, from 1870 to 1880, upwards of nine thousand tons of lead were produced from the slags and scoriæ left by ancient miners in the district of the Mendipp Hills, in England.[2] Special furnaces have been erected in Spain to rework the

[1] Schoolcraft, Views of the Lead Mines, etc., p. 93.

[2] Hunt, British Mining, p. 33.

old slags of the Carthaginian, Roman, and Moorish smelter. The slag heaps in the vicinity of the Laurium mines, in Greece, exploited before the Christian era, are being reworked to-day and yield large profits; and the slags of the early Missouri smelters have found a market at the smelting-works in St. Louis. In early days, at the mines of the Mississippi valley, cerussite or native lead carbonate, called "dry bone" by old Missouri miners, was also thrown aside as worthless.

These primitive furnaces, notwithstanding their wastefulness, are better adapted in some cases, on account of their simplicity and inexpensiveness, than those of more complete and perfect construction. In the mountains of Peru, the natives, depending for fuel, as they are obliged to do, solely upon the dried dung of the llamas and huanacos, successfully smelt the argentiferous lead ores in furnaces of the most primitive construction. When the fuel in the neighborhood of the furnace is exhausted, they abandon the place and build another furnace in a more favored locality.[1]

The furnaces heretofore described depended, as has been seen, solely upon natural air-currents for a blast; but the use of the bellows for producing an artificial blast antedates written history. On the walls of a tomb in Egypt, dating, according to Wilkinson, to 1500 B. C., a scene is depicted representing the use of bellows in smelting iron. The fire is made upon the ground and is urged by a blast produced by two pairs of bellows worked by two men. The operator, standing with a bellows under each foot, pressed each alternately, raising with a string the exhausted skin.[2] The prophet Ezekiel refers to an artificial blast in the passage, " As they gather the silver and brass and iron and lead and tin into the midst of the furnace, to

[1] Tschudi, Travels in Peru, etc., p. 199.

[2] Wilkinson, The Ancient Egyptians, vol. ii. p. 306.

blow the fire upon it, to melt it."[1] Watson says: "In comparatively modern times the furnaces of the Greeks were located on the banks of streams, so that the bellows for supplying the blast were driven by water-power; but in the mountains of Macedonia, where mines were wrought in the days of Philip, great heaps of slag have been discovered so far above any river that the bellows could not have been worked by water-power, and the smelters must have depended upon natural air-currents." [2] But the bellows may have been worked by men, as Leger, quoting Ledoux, describes an ancient furnace discovered in the midst of a heap of scoriæ surrounding some ancient works in Attica. It was very low, cylindrical, about three feet in diameter, and was constructed of refractory material. The fuel was charcoal, and the blast was furnished by bellows worked by men. Above the furnace high chimneys created a draught and carried away the deleterious fumes of lead.[3]

In Peru the Spaniards introduced windmills to work the bellows of the smelters.[4] According to Percy, in some districts of India the natives still smelt galena in a small way by simple primitive methods, in some cases using an artificial blast, but generally depending upon natural air-currents; and the same author quotes from an article published in 1668 in "Philosophical Transactions," which describes a smelting-furnace as a hearth about five feet high, set upon timbers so that it could be turned like a windmill, to take advantage of the wind at all times.[5] The native Mexicans smelt lead to-day in furnaces of simple construction, and provide a blast by the use of a common

[1] Ezekiel xxii. 20.
[2] Watson, Chemical Essays, vol. iii. p. 265.
[3] Leger, Les Travaux Publics, etc., p. 715.
[4] Garcilaso de la Vega, Royal Commentaries, etc., p. 347.
[5] Percy, The Metallurgy of Lead, p. 537.

blacksmith's bellows worked by hand.[1] The Japanese, according to Pumpelly, smelt lead in a furnace constructed as follows: "A pit is dug in the ground and lined with a mixture of clay and charcoal, forming a sort of crucible; the ore is mixed with charcoal and is charged into the furnace, when the blast, which is produced by a bellows and is introduced into the crucible through a clay nozzle, is applied. After the ore is partially melted a quantity of pig iron, broken into small pieces, is added to combine with the sulphur; after a time the fire is withdrawn, and the mass is allowed to cool, when the matte or scum which rises to the top is removed. This operation is repeated several times, until the surface of the lead is clean, when it is cast into bars.[2] In the mining district of Ajmeer, in India, the natives smelt lead in small blast-furnaces, the blast being produced by bellows made of half-dressed goatskins, each bellows being worked by one man. The ore is powdered and washed, then mixed with its own weight of cow's-dung, rolled into balls, and dried in the sun. The balls of dried ore are fed into the furnace alternately with charcoal, and after three or four hours' firing the furnace is tapped, the slag drawn off, and the lead cast into moulds.[3]

Agricola describes several forms of furnace for smelting lead ores, which do not differ materially from the primitive furnaces of the Greeks and Romans. They are very small, and seem to have been used for smelting the ores of iron and copper as well as of lead. In the north of Italy the smelters first cleaned the ore, then put it into a crucible, which was placed in an open furnace, provided with a rectangular opening at the back to furnish a natural air-current; wood was used as fuel, and the melted lead flowed

[1] United States Consular Report No. 67 (Washington, 1886), p. 493.

[2] Pumpelly, Across America and Asia, p. 145.

[3] Percy, The Metallurgy of Lead, p. 295.

into a receptacle in front of the furnace, from which it was ladled into moulds. In Saxony a similar furnace was used, but charcoal was employed as fuel. In Westphalia a pit was dug, or a hollow place in the side of a hill was utilized, much in the manner already described as prevailing in early days in England. Agricola also describes a method of collecting and preserving, in a chamber above the smelting-furnaces, the products which either in vapor or fine dust ordinarily escape by the chimney and are lost. These upper chambers, into which the tops or chimneys of the furnaces projected, were provided with sloping walls and a concave ceiling, and with a flue, the opening of which was near the floor of the chamber. The gaseous products of combustion rising in the chimneys of the furnace passed into the chamber, the metallic vapors condensed, and were deposited on the walls and floor, while the smoke and uncondensed gases passed into the open air through the flue.[1]

Wood and charcoal were principally used for fuel by the ancient smelter, though peat was used in England as early as 1201. In that year King John granted to the miners of Cornwall and Devon the right to dig ore and turves.[2] The introduction of mineral coal for smelting purposes dates perhaps from 1678, in which year, and again in 1692, letters-patent were granted for smelting down lead with pit-coal or sea-coal instead of wood and peat.[3]

In England and the United States these primitive furnaces were replaced by a species of blast-furnace called an "ore-hearth," a modification of which, called the American ore-hearth, was and still is used in some districts in

[1] Georgius Agricola, De Re Metallica, pp. 320, 322.

[2] Phillips, Thoughts on Ancient Mining.

[3] Wm. Maitland, F.R.S., The History of London, from the Foundation by the Romans to the Present Time (London, 1739), p. 627; also Percy, The Metallurgy of Lead, p. 218.

the United States. These furnaces are well adapted for the reduction of the purer ores. The reverberatory furnace soon displaced the ore-hearth in many districts in England and in the United States, and it is now almost exclusively used in the treatment of the purer ores; the more refractory ores, or those carrying silver and other metals in notable quantities, are submitted to a preliminary treatment and smelted in blast-furnaces, the construction of which varies with the locality, the character of fuel, and other circumstances.

The ancient smelters did not succeed in recovering more than two thirds of the lead present in the ore; and this is not surprising if we consider their crude methods. As a consequence it is found that in all ancient mining districts the richer and purer ores only were worked, the leaner being discarded as unprofitable. It is probable that an ore containing twenty per cent of lead would have been neglected. The improvement in modern methods becomes strikingly apparent if we compare the work at Commern, in Germany, in 1864. The ore is a white sandstone, bearing lead in small pellets from the size of a pin's head to that of a pea. In the year mentioned one million two hundred and four thousand nine hundred and fifty-three tons of this sandstone was moved, producing twenty-two thousand three hundred and ninety-seven tons of dressed ore, or one and one-half per cent of lead.[1] The slags of the old smelters frequently yield fifteen to twenty per cent of lead.

The purification of metals by fire is mentioned by Moses, and frequent references to this subject in the sacred writings clearly show that at that time not only the recovery of metals from their ores was well known but also the more difficult and much more elaborate and refined metallurgical operation of separating the metals from each

[1] Percy, The Metallurgy of Lead, p. 351.

other, after the grosser impurities had been removed. Pliny is the earliest writer who gives any detailed statement of these processes; but his descriptions are incomplete and obscure, and show that he was not familiar with the operations he describes. He says there are two different sources of "black-lead," meaning by this term the substance we know as metallic lead; "it is procured," he continues, "from its own native ore, when it is produced without the intermixture of any other substance;" "black-lead is also procured," he says, "from an ore which contains it in common with silver, the two metals being found together."[1] In the first case Pliny unquestionably refers to the purer galenas, which, upon the application of heat under proper conditions, readily part with the sulphur, producing metallic lead. In the second case he refers to argentiferous galenas; and he proceeds to describe the result of the process of smelting these ores as follows: "The metal which first becomes liquid is called 'stannum,' the next that melts is the silver, and the metal which remains is 'galena.'"[2] The obscurity of this passage has provoked much discussion, and caused an extraordinary amount of research in the effort to make the description conform to modern practice. Beckmann thought the ancient method did not vary much from the modern. "The ore was first crushed and washed, then roasted, and finally smelted in a furnace, resulting in the production of a regulus, consisting of lead and silver." This product was called "stannum," and is the same known to the German smelter of to-day as "*werk*," or "*werkblei*," and by our smelters as base bullion, so named to distinguish it from gold or silver bullion. This "stannum was treated in a furnace specially constructed for this operation, and provided with a hearth of lixiviated ashes to separate the silver from the lead and other metals." This particular process Pliny fails to

[1] Pliny, Natural History, book xxxiv. chap. xlvii. [2] Ibid.

mention, probably because he was ignorant of the details of the operation. The product obtained by this second process, which we term "cupellation," was silver and protoxide of lead, or litharge as we term it, but called by Pliny "galena," — a name by which we distinguish one of the principal ores of lead.[1] If this last substance, litharge, be heated, and the oxygen expelled, metallic lead remains. This rendering of the account given by Pliny is intelligible, and quite in accordance with modern methods, by which the ore is first pulverized, washed, and roasted, then smelted in a blast-furnace, producing a regulus composed of the lead, silver, and other associated metals. This regulus, or base bullion as we term it, is then treated in a reverberatory furnace, for the purpose of eliminating some of the associated metals; next, the silver is separated from the now partially purified product by cupellation, or by some more modern method, and the litharge is reduced to the metallic state by treatment in a blast-furnace.

The confusion created by the misapplication of terms by Pliny, due to his ignorance of metallurgical processes, is most perplexing. He calls the protoxide of lead, which we know under the name of litharge, "galena." He also says that "galena is the vein of lead found near the veins of silver ore," and again says that "molybdena is a compound of silver and lead, which is also known by the name 'galena.'"[2] Pliny also says: "There are two kinds of lead, — 'white lead,' and 'black lead;' the white is the most valuable. It was called by the Greeks 'cassiteros,'

[1] John Beckmann, History of Inventions, etc., Bohn's edition (London, 1881), vol. ii. p. 211.

[2] Pliny undoubtedly used the word "galena" to signify native lead-sulphide, the most common ore of lead, and the term is now used only in connection with that substance, while the name molybdena, meaning "a mass of lead," or molybdenite, has been appropriated to a lead-colored mineral formerly considered to be a species of lead ore, but in comparatively recent times recognized to be a sulphide of a very rare metal, which has received the name "molybdenum."

and there was a fabulous story of their going in quest of it to the islands of the Atlantic." [1] Pliny describes the ore of this white lead in such a manner as to leave no doubt that tin was the substance referred to. As above stated, the product of the first smelting of argentiferous lead ore is a regulus consisting of lead and silver, with perhaps other metals associated in inconsiderable quantities. This substance Pliny terms "stannum," a name which has been used for many centuries to designate the metal tin, and from which the name for tin in the French and some other languages has been derived. Tin was one of the first metals known, and its combination with copper, forming bronze, was among the first metallurgical operations discovered.

Herodotus, Strabo, and other ancient authors, refer to the Islands of the Cassiterides as one of the principal sources of the supply of tin to the ancient world,[2] and the references are generally considered to apply to the Scilly Isles, lying off the coast of Cornwall; but Pryce, and other authorities, doubt that tin in any considerable quantities was ever produced in these islands; they speak of the almost entire absence of any indications of mining on the islands in ancient times, and refer to the fact that in modern times the ores of tin have not been found there.[3] In Devon and Cornwall, on the contrary, there is evidence of extensive works in early, and probably pre-Roman, times, and ever since the period of Roman occupation tin has been produced there in great quantities. These writers contend, therefore, that Devon and Cornwall must be the Cassiterides of the ancients, and that the Phoenicians supplied the world for centuries with British tin, obtained from these districts in their expeditions from

[1] Pliny, Natural History, book xxxiv. chap. xlvii. p. 54.

[2] Herodotus, p. 175; Strabo's Geography, book iii. chap. ii.

[3] Pryce, Mineralogia Cornubiensis, introduction, p. 4.

the colony at Gades, in Spain. Sir George Lewis, while he endorses the theory that the tin sold by the Phoenicians to the Greeks was principally procured from Devon and Cornwall,[1] doubts that this trade was conducted, as so many writers affirm, by sea, through the Straits of Gibraltar, and accepts the account given by Diodorus Siculus that tin was ferried across the channel in the coracles, or hide-boats, of the ancient Britons, and thence transported on the backs of horses to the mouth of the Rhone, whence the Phoenician ships could distribute it to the nations bordering upon the Mediterranean.[2] The Phoenicians were undoubtedly masters of the tin trade for centuries; but as India, in remote ages, probably supplied the ancient Egyptians with tin,[3] and as the Phoenicians communicated with India by caravan across Arabia, and by other routes, supplies may have been brought from Asia, or the mines of Spain may have furnished enough for the demand at that time. Pliny, Strabo, and other ancient writers, refer to the occurrence of tin in Lusitania and Galicia,[4] and Herodotus says he is ignorant of the location of the Cassiterides, "from whence we are said to get our tin,"[5] while Pliny refers to the statement that tin was procured from islands in the Atlantic as a fabulous story. Professor Rhys, of the University of Oxford, says, "There is not a scrap of evidence, linguistic or other, of the presence of the Phoenicians in Britain at any time."[6] And Sir John Lubbock remarks upon the entire absence of traces of ancient commerce in Cornwall, and laments that so few

[1] Sir George C. Lewis, Historical Survey of the Astronomy of the Ancients (London, 1862), p. 451.

[2] Diodorus Siculus, book v. chap. ii.

[3] Wilkinson states — Ancient Egyptians, vol. ii. p. 134 — that bronze vessels, dating to more than two thousand years before our era, have been found in the tombs of ancient Egypt.

[4] Strabo, book iii. chap. ii. See also Pliny, book xxxiv. chap. xlvii.

[5] Herodotus, p. 175.

[6] J. Rhys, M.A., Celtic Britain (London, 1884), p. 47.

Phoenician remains are preserved in the museums of Great Britain.[1]

Pliny's name for tin was "plumbum album," or "plumbum candidum,"—white lead. He says: "The Greeks called it 'cassiteros,' and hence the name of the Islands Cassiterides, from whence it was said to have been procured." In the Bible the Hebrew word "bedil" was rendered by the Greek translators "cassiteros," and this in turn is translated into English "tin," though in some places the word "lead" would be more appropriate. Pliny considered that tin was a variety of lead, and not a separate and distinct metal, and confounded it with the Roman "stannum," the product of the first smelting of argentiferous lead ores. This is not surprising, as this substance, owing to the presence of other metals, even in small quantities, is less easily affected by atmospheric influences than pure lead, retains its lustre longer, and appears much like the metal tin. It is clear therefore that little dependence can be placed upon these words, when they occur in ancient writings, except that they indicate some metal differing from gold, silver, copper, iron, and even ordinary lead.

Beckmann and other authorities have treated this subject at considerable length, and argue that, in Pliny's time, tin was not so abundant as is implied in the statements of ancient writers. Beckmann thought that tin was sparingly supplied from Spain and Gaul, but that it must have been scarce and exceedingly dear, and consequently could not have been used for such common purposes as is indicated in the works of ancient authors. He contends that the translators of the Books of the Prophets have used the word "cassiteros," which signified tin, when "stannum," a mixture of lead and silver, was the proper translation. In this opinion he is supported by scholars profoundly

[1] Sir John Lubbock, Prehistoric Times, p. 74.

versed in Oriental history and philology, and his views are adopted by many writers of modern times.[1] If Beckmann is correct the "plummet" referred to in Zechariah was of lead, as we should suppose it to be, and not of tin, as it would be termed if the word "bedil" had been translated as it is in other parts of the Bible.[2]

On account of the close resemblance which exists between the substance called "stannum" by the Romans and the metal tin, and the confusion which existed for many centuries regarding their names, it is thought that in early days these metals were used indifferently for various purposes.[3] It is probable, as Moore points out, that the Greeks included under the name "cassiteros," alloys of tin with lead, and perhaps with other metals, — as the French use to-day the word "étain," to signify tin, and also to designate pewter, which is an alloy of tin with lead;[4] and Phillips thought the Roman stannum was "an alloy of tin with lead or with antimony, of lead with silver, or variable mixtures of metals often associated in nature."[5]

Stannum was largely used in ancient times in the manufacture of articles for domestic and for other purposes, perhaps before the art of separating silver from lead was discovered; and after that period such as contained what was considered too small a percentage of silver to be

[1] Beckmann, History of Inventions, etc., vol. ii. p. 208.

[2] Zechariah iv. 10. If we apply Beckmann's argument to the references to tin in Homer it would show that the greaves of Achilles and the bands and bosses on his shield were not of tin, forged by celestial workmen, as the translators of Homer have it, but were of the substance called stannum by Pliny, and which is known in our smelting-works as base bullion. This proposition seems absurd enough; but if the ornamentation of the shield of Achilles is assumed to have been of tin it supports Beckmann's argument respecting the scarcity and consequent dearness of the metal, as the poet would doubtless describe the armor forged by the gods as being of the rarest and most costly materials.

[3] Kopp, Geschichte der Chemie.

[4] N. F. Moore, Ancient Mineralogy.

[5] John Phillips, Thoughts on Ancient Metallurgy.

profitably recovered continued to be so employed. Beckmann believes that many, perhaps the greater number of articles for domestic use said to have been made of bronze, and which some writers contend were made of tin, were made of Roman stannum, which, if rich in other metals, and thus more difficult of fusion, was more suitable for such purposes than copper. He quotes Suetonius as authority for the statement that the Emperor Vitellius took from the temples all the gold and silver, and substituted aurichalcum and stannum.[1]

A large trade certainly existed in this substance in ancient times, conducted probably by the Phoenicians, who, if not smelters of lead, were undoubtedly chiefly instrumental in the distribution of metals among the ancient nations. The prophet Ezekiel, referring to them, says, "With silver, iron, tin, and lead they traded in thy fairs."[2]

Isidore, of Seville, in the sixth or seventh century (he died A. D. 636), says: "There are two kinds of lead, the black and the white, the latter of which is the best, and is found on islands in the Atlantic Ocean, also in Lusitania and Galicia." He describes what we may suppose to be an ore of tin, which he says contains gold. He gives directions for separating the gold and securing the white-lead — tin — by smelting. Black-lead, he informs us, is abundant about Cantabriam, and its origin is two-fold: one vein produces lead mixed with silver, and upon being subjected to heat the first product is stannum; the second is silver; and that which remains, added to the ore and reheated, becomes black-lead.[3]

This quotation is from an encyclopedic work which is an epitome of the scientific knowledge of the seventh century. Tin, therefore, was still termed plumbum candidum, or

[1] Beckmann, History of Inventions, etc., vol. ii. p. 213.

[2] Ezekiel xxvii. 12.

[3] Divi Isidori Hispal. Episcopi, etc.

plumbum album,—white lead,—and the first product of smelting argentiferous lead ores was called stannum, our technical name for tin.

Geber, in the eighth century, recognized the metal tin, and mentioned several of its peculiarities, especially its distinctive characteristic, the peculiar crackling noise made when it is bent or broken,—its "cry," as it is called,—and the Greek word *cassiteros* began to be translated *stannum,* the technical name since that time signifying tin.

Articles for domestic and other uses continued to be made of stannum, or to use its modern German name, "werkblei," as late as the sixteenth century, and Beckmann mentions old vessels for use in church service which he considered to be of the same substance.[1] Agricola describes stannum in several places in his work, "De Re Metallica," as a compound of black lead and silver; and in his second index, in which he gives the equivalent German expression for the Latin names of the metals, metallurgical processes, etc., described in his work, he translates stannum by the old German term "werkplei," a substance which is the product of the first smelting of argentiferous lead ores.[2]

Pliny says, "When copper vessels are coated with stannum they produce a less disagreeable flavor, and the formation of verdigris is prevented." True tin is probably intended here, as he continues, "At the present day a counterfeit stannum is made by adding one third of white copper to two thirds of white lead; it is also counterfeited in another way, by mixing equal parts of white and black lead, this last being what is called argentarium." "There is also," he says, "a composition called 'tertiarum,' used for soldering pipes, a mixture of two parts of black lead

[1] Beckmann, History of Inventions, etc., vol. ii. p. 214.

[2] Agricola, De Re Metallica, Index Edition, 1556.

and one of white."[1] Both of these alloys were used in the composition of statuary bronze.

Beckmann explains these obscure statements by saying that Pliny thought that tinning should be done with pure tin, but that unprincipled men sometimes used a mixture of tin with lead.[2] Pliny, however, adds to the confusion by saying that "white lead, meaning tin, without being mixed with another metal is of no use for anything,"[3] which perhaps proves that all tin was mixed with lead in some degree; and Beckmann finally concludes that tinning with pure tin was of rare occurrence.[4]

The method adopted by the ancient metallurgist, in the somewhat complex art of separating the silver contained in the stannum from the lead, is the same as that known, and in use to-day, under the term "cupellation." This process is based upon the principle that when silver is heated to a temperature far beyond its melting-point in the presence of atmospheric air it remains unaltered; and this is true whether the silver alone is present, or whether it is mixed with other metals. Lead, on the contrary, when subjected to a high temperature under the same conditions, very readily oxidizes, and the liquid metal changes to a yellowish-brown flaky powder, which we know under its chemical name of lead oxide, or its common name litharge.

If a mixture of lead and silver is subjected to a high

[1] Pliny, Natural History, book xxxiv. chap. xlviii.

[2] Beckmann, History of Inventions, etc., vol. ii. p. 221.

[3] Pliny, Natural History, book xxxiv. chap. xlviii.

[4] Beckmann, History of Inventions, etc., vol. ii. p. 221. The ancients were well acquainted with the art of tinning. Pliny says: "The method of coating articles of copper with white-lead — tin — so as to be scarcely distinguished from silver was discovered in the Gallic provinces by the Bituriges."[1] The deleterious effect of lead upon the human system was also well known. Pliny refers to it, and Galen recommends keeping medicines in glass in preference to tinned vessels, as all tin was probably adulterated with lead.

[1] Pliny, Natural History, book xxxiv. chap. xlviii.

temperature, with access of air, in vessels of refractory material, the lead eagerly takes up oxygen, and assumes the form of a flaky brown powder, which may be removed, while the silver is found unchanged at the bottom of the vessel. This process is probably referred to in the following passage from Jeremiah: "The bellows are burned, the lead is consumed of the fire, the founder melteth in vain, for the wicked are not plucked away; reprobate silver shall men call them, for the Lord hath rejected them;" [1] and again, "The house of Israel is become dross; all they are brass, and tin, and iron, and lead, in the midst of the furnace; they are even the dross of silver;" [2] and, "I will turn my hand upon thee and purely purge away thy dross, and take away all thy tin." [3]

According to Leger, though this metallurgical process was commonly known in the East, and practised before the time of Cyrus (600 B. C.), cupellation was not practised in the West until much later.[4] Agatharchides describes the process of purifying gold by melting it in earthen pots, together with tin and lead, to which salt and barley-bran was added; the fire, he says, was kept up during five successive days.[5] Strabo refers to cupellation when he says that the silver ore of the mines was washed five times, and the dregs were then melted, and the lead being poured off the silver was obtained pure. He describes the silver furnaces as being constructed so that "the pestilential vapors of the lead were raised and carried off." [6] The use of lead in refining gold is mentioned by Theognis, who lived in the sixth century B. C.[7]

[1] Jeremiah vi. 29, 30. [2] Ezekiel xxii. 18.
[3] Isaiah i. 22–25.
[4] Leger, Les Travaux Publics, etc., p. 716.
[5] Agatharchides, De Rubro Mari.
[6] Strabo's Geography, book iii. chap. ii.
[7] Moore, Ancient Mineralogy, p. 44.

Evidences of the practice of this method of refining argentiferous lead are abundant in the ancient mining districts in the Old World. Near Cartagena, in Spain, pigs of lead of undoubted Roman smelting have been found, with cakes of silver lying near them. In the province of Barcelona great heaps of litharge have been discovered near the site of an ancient furnace. In many ancient mining-camps in France evidences are abundant of this method of separating silver from argentiferous lead. Remains of ancient cupelling furnaces have been discovered near Almeria, in Spain; quantities of litharge have been found mixed with the scoriæ near old foundries in Greece.[1] Geber understood the process of cupellation; and Theophilus, who wrote in the eleventh century, describes minutely the method of preparing the crucible, or cupel, for the purification of silver, and with careful detail gives directions for conducting the process.[2] Agricola describes a smelting-house with the necessary apparatus for separating silver from lead by cupellation, and illustrates his description with wood-cuts, in which the smallest details are treated in the most painstaking manner. The cupelling furnaces are much like those in use to-day in Germany. The blast was furnished by bellows operated by water-wheels; the iron cover, or hood, was removed or put into position by means of a crane provided with a system of gearing, the power being supplied by men who worked a crank-shaft.[3]

The native Peruvians seem to have independently discovered this metallurgical process; they made moulds of clay called "guayras," in the shape of a flower-pot, with many holes in them; they filled these with ore mixed with

[1] See Daubrée, L'Exploitation des Mines, etc.; also Leger, Les Travaux Publics, etc., pp. 698, 715.

[2] Diversarum Artium Schedula, Theophilus, monk, translated by Hendrie (London, 1847), p. 227.

[3] Agricola, De Re Metallica, pp. 324, 382.

charcoal, and taking them to the mountains, to take advantage of the natural air-currents, fired them; the product of this fusion was afterwards further refined at their houses, the blast being secured by the use of small hand-bellows.[1] Garcilaso de la Vega describes the Peruvian method of recovering silver from its ores as follows: "The silver for the most part is extracted from the 'Hatun Potossi,' in the melting of which they at first found great difficulty, for not being able to make it run, it burnt away or evaporated in smoke, of which the Indians could not penetrate the cause, nor discover a remedy. But as necessity and covetousness make men ingenious and contriving, so particularly the Indians were infinitely industrious to find out some way to melt their gold and silver. At length, after many experiments, they happened to try the melting of a baser sort of metal, which the 'lesser Potossi' produced, consisting for the most part of lead mixed with silver, the which yielding more easily melted and run, and this being put in the melting-pots, together with the fine silver and gold, would immediately cause them to melt and dissolve; for which reason the Indians gave it the name of 'curuchee,' which signifies anything that dissolves." This was the first smelting, and was conducted on the mountain; the product of this operation was then taken to their houses, where it was subjected to a second smelting, when, by the use of a blow-pipe, the lead was completely oxidized, or "burnt out," and the silver recovered.[2]

The natives of India were acquainted with this process three hundred years ago. Digging a hole in the ground they worked up a composition of moistened ashes, with which they plastered the cavity, making a sort of dish, or

[1] The Travels of Pedro de Cieza de Leon, translated by C. R. Markham (London, 1864), p. 389.

[2] De La Vega, Royal Commentaries of Peru, p. 346.

cupel; they put the ore and lead into this vessel or furnace, fired it, and repeating the operation they finally recovered the silver.[1]

It is not the purpose or the scope of this work to discuss, or even to describe in detail, modern processes for the recovery of lead from its ores, and for the final purification of the metal. The subject is treated in the most complete and exhaustive manner by Percy, and other authors of recognized authority, and to these the reader is referred for technical details.

Modern smelting-processes are many and varied, the differences arising principally from the character of the fuel, or of the ore, the means of transportation, or other local causes, which determine the method employed. The purer sulphide ores are generally first crushed, then washed to remove the earthy impurities, dried, and subjected to the operation of smelting, which is generally conducted in reverberatory furnaces. The process may be described as consisting of two operations: first, in roasting the galena with access of air, which converts the ore into a mixture composed of the oxide and the sulphate, with some undecomposed sulphide; second, by increasing the temperature these products are made to react upon each other and metallic lead is produced, the oxygen and sulphur combining and escaping as sulphurous acid-gas. In some districts the purer galenas are treated in the ore-hearth, which is a small rectangular blast-furnace. In this furnace a portion of the ore is oxidized by the heated blast, and a chemical reaction occurs between the oxidized products of the ore affected and portions of the ore lying underneath, by which metallic lead is released.

In smelting lead advantage is sometimes taken of the fact that sulphur has a greater affinity for iron than for lead, and if iron is brought into contact with molten sul-

[1] Percy, The Metallurgy of Lead, p. 211.

phide of lead it will — as soon as it has acquired the proper temperature — combine with the sulphur, while metallic lead is set free. Pure iron is sometimes used for this purpose, but cinders and other secondary products may also be employed.

The ores in which lead is found associated with notable amounts of silver, and with other metals, require a more elaborate treatment, which varies somewhat to meet local conditions, but usually the scheme is substantially as follows: the ore, after being crushed, is treated to expel the sulphur, arsenic, antimony, etc., and to convert the metals contained in it into oxides; this operation is usually conducted in a species of reverberatory furnace. The roasted ore is now transferred to a blast-furnace to reduce the lead and silver to a metallic state; the products of this smelting are the argentiferous lead, called in this country "base bullion," speiss, matte, slag, and other secondary products, some of which are utilized by subjecting them to further treatment.

The base bullion, which contains besides the lead and silver some of the other metals which were associated with them in the ore, may be treated for the separation of its constituent metals in one of three ways: by cupellation, the ancient process already referred to; by crystallization, or Pattinson's process, so named in honor of its inventor, or by what is known as the zinc process.

The process of cupellation is conducted in a furnace specially constructed for the purpose, and provided with a floor or hearth carefully prepared of bone ashes. The argentiferous lead is introduced into the furnace, and is subjected to a high temperature by means of a blast; the lead rapidly oxidizes, forming litharge, which may be removed, carrying with it the oxides of several other metals which may be associated with it in the base bullion; fresh portions of argentiferous lead, or base bullion, are

added from time to time until the contents of the furnace have been highly concentrated, when the final operation is conducted in another furnace with a freshly prepared hearth. Some of the litharge is absorbed in the hearth, but the loss of lead is rarely more than five per cent. The method here described is known as the English process. The German method differs slightly in the manner of treatment and in the construction of the apparatus; the principle, however, is the same.

The Pattinson process is based upon the following phenomenon: if a mixture of silver and lead heated above the melting-point is allowed to cool nearly to its fusing-point, while being stirred, crystals will form, and include much less silver than that portion of the lead which remains liquid; if this operation is repeated nearly complete separation of the silver will result. In practice a large number of kettles are arranged in rows, and into the first the argentiferous lead is placed, fire is raised, and after the mass is thoroughly melted the fires are drawn, and while cooling the metal is constantly stirred; crystals soon form, and are removed with a ladle pierced with holes, which allow the liquid to fall back into the kettle, while the crystals, which are of nearly pure lead, are thrown into a second kettle. This process is repeated by reheating and passing the crystals on from one kettle to another, until they consist entirely of pure lead, and the liquid lead carries a very large percentage of silver, which is then removed to the cupelling-furnace and the silver entirely separated by the old method.

A modification of this process has been adopted by many refiners in France and in England, by which the agitation of the melted lead is produced by introducing steam at a pressure of three atmospheres, instead of mechanical or machine stirring; and only two kettles are used instead of the large number required by the original pro-

cess. The apparatus employed consists of two kettles placed at different levels. The lead to be treated is melted in the upper kettle, and having been skimmed is tapped into the lower one and steam is turned on. When crystallization has reached the desired point the rich lead is run off into circular moulds sunk in the ground, and the crystals are left in the kettle to mix with the next charge. The rich lead, after cooling, is moved in blocks weighing two tons or more by means of a crane, and is piled at a convenient distance from the furnaces, blocks of the same degree of richness being piled together. When one pile is worked off the next series are successively crystallized. When the separation is complete the pure lead is run into moulds, and the concentrated rich lead treated for the purification of the silver. This process is found to remove copper, nickel, and other impurities present in small quantities much more effectively than the old hand process.

The lead produced by Pattinson's process is remarkably pure, as the associated metals are practically completely eliminated by the repeated heating and the removal of the scum formed by the oxidized products. Before the invention of this method (patented in 1833) all the silver recovered from argentiferous lead was obtained by the old method of cupellation. The new method not only reduced the cost of separating the silver, but it enabled the metallurgist to treat lead containing only three ounces of silver to the ton, while previous to that time most of the commercial lead contained as much as fifteen ounces to the ton.[1]

The extraordinary amount of silver found in lead which had been stripped from the roofs of ancient buildings has given rise to the statement that silver was purposely added to the lead, or that by some inscrutable process silver had been spontaneously produced. The fact is, however, that

[1] Lamborn, The Metallurgy of Lead and Silver, p. 146.

the ancients did not think it worth the cost to desilverize lead which carried an amount of silver modern smelters would have esteemed highly profitable. It is possible also that by the action of atmospheric influences portions of the grosser metal had become oxidized, or carbonized, and being exposed to the wind and rain had disappeared, the silver and lead remaining forming a rich alloy.

The process of refining most commonly adopted in this country is that known as the "zinc process." When a mixture of lead and zinc, melted at a high temperature, is allowed to cool, a nearly complete separation of the metals takes place, the zinc, on account of its higher melting-point and lower specific gravity, solidifies first and forms a crust, which floats upon the surface of the liquid lead so that it may be removed by skimming. In argentiferous lead the silver becomes concentrated in the crust of zinc, and may be removed with it.

The usual practice is to treat the base bullion in a reverberatory furnace for the oxidation and the removal by skimming of some of the impurities, as copper, antimony, arsenic, etc.; it is then run into kettles and heated, a small quantity of zinc is added, the heat increased, and the molten mass continually stirred to thoroughly incorporate the zinc. This stirring was originally performed by hand, but a jet of steam issuing from a pipe inserted into the molten mass is found to answer the purpose better, and is now generally adopted. The fires are now banked, and the mass is allowed to cool, the crust is removed with a ladle, the lead is reheated, more zinc is added, and it is again cooled and skimmed. This operation is repeated the third time, when the separation of the silver is usually found to be complete. The desilverized lead has to be again treated to remove traces of zinc — commonly by passing super-heated steam into the molten mass, oxidizing the zinc, which is then removed from the surface by skimming,

when the liquid is ready to be cast into moulds, forming commercial pig-lead. The crusts, which contain the zinc, silver, gold, copper, and other metals, are treated for the recovery of the silver and gold, and the silver is finally separated by the cupellation of the concentrated bullion.[1]

[1] See Percy, The Metallurgy of Lead; Lamborn, The Metallurgy of Lead and Silver; and Hahn in Mineral Resources of the United States, Washington, 1883, — from whose works the descriptions of modern processes have been largely derived.

CHAPTER VII.

THE USES OF LEAD IN ANCIENT TIMES.

LEAD is so rarely mentioned in the works of ancient writers that we might infer it was not in general use; but trade and commerce were probably much more extensive in ancient times, and the art of working metals was better understood than the direct testimony of ancient history indicates; and so common a metal as lead was doubtless an important article of exchange and barter, and was in common use among the civilized nations of the East.

The ancient Greeks and Romans used lead in large quantities, and for many purposes; but the Egyptians and Assyrians, if we may rely upon the results of the explorations of archæologists and travellers in the ruins of those ancient empires, found but little use for this metal. The Egyptians glazed their pottery with lead, and Wilkinson mentions its use in soldering coarse ware, and assigns the specimen observed by him to a Pharaonic age.[1] It is also mentioned as being among the spoils brought home by the armies of Thotmes III. from their expeditions to Mesopotamia and to the country of the Phoenicians. Leaden objects of ancient Egyptian origin are rare in the museums of Europe, and it is possible that this metal was not in common use in that country. At

[1] Wilkinson, The Ancient Egyptians, vol. ii. p. 163.

the Berlin Museum a few leaden objects from the ruins of ancient Egypt are preserved, and have been described by Hoffmann. Among them are figures representing a winged woman, a grasshopper, etc., and a shield about five inches long and three and a quarter inches wide, which has inscribed upon its face several symbolic representations. These objects were found upon the breasts of mummies. A leaden figure representing a cat in a sitting posture is thought to have been used as an amulet. In the Museum at Turin there are preserved two figures cut out of thin plates of lead and made to represent birds. One of these figures is covered with a thin layer of tin. In the temple of Rameses III., at Medinet-Abu, plates or bricks of lead have been found covered with inscriptions in which a word occurs which may be translated *lead*.[1]

Lead is not mentioned in the oldest of the books of India, but in the Yajur Veda it is referred to as being in use as a weaver's weight. It was also used to purify silver, as a charm, and, curiously enough, in medicine as a remedy for indigestion. The women used one of its products, red lead, as a cosmetic.

The Assyrians acquired a high degree of perfection in the art of working metals, and the graceful shapes of their ornaments and utensils indicate the attainment of a refined taste. It is probable that this nation found many uses for lead.

The Babylonians built great dams and embankments to confine the Euphrates within its bounds. In the interior of the city these walls were built of massive stones, forming great quays.[2] Queen Nitocris turned the river as it flowed through the city, and carried over it a bridge, the huge stones of which as well as those forming the embank-

[1] K. B. Hoffmann, Das Blei, bei den Völkern des Alterthums (Berlin, 1885), p. 6.

[2] Heeren, Historical Researches, vol. ii. p. 135.

ments were bound together with clamps of iron, secured in the stone by running in molten lead. The hanging-gardens of Babylon are described as being four hundred feet square, built upon immense arches carried to a height of fifty cubits; upon the top flat stones sixteen feet long and four feet wide were first laid, upon these a bed of reeds was spread, then a layer of bitumen, after which came two courses of brick or tile, and the whole was finally covered with sheets of solid lead carefully soldered to retain the moisture of the soil.[1]

The oldest coined money known is that of Lydia. It is an alloy of gold and silver, called by the ancients *electrum;* but the Hindus say that the Chinese in ancient times flattened lead by hammering, and used it as money. According to De Goguet, the Chinese coined money as early as the reign of Hoang Ti,[2] 2000 B. C. Lead is mentioned in the Atharva Veda as in use as money. The bronze coinage of Greece and Rome, dating from 500 to 50 B. C., contained a notable amount of lead, ranging from three to thirty per cent. After 50 B. C. the proportion of lead used was much less, and was so inconsiderable as to warrant the supposition that its presence was accidental. In the earlier coinage it has been suggested that lead was added to the alloy to render it more fusible, as at that day coins were cast, and not stamped as in later times.[3] Leaden tokens, or medals, of ancient Greek and Roman manufacture have been found in great numbers, and it has been suggested that some may have been used as money in ancient times. The early coinage of Greece was counterfeited by encasing lead with the precious metals and imitating the official stamp. It has been said that at one time, owing to a scarcity of the precious metals, the state resorted to this

[1] Diodorus, vol. i. p. 108.
[2] De Goguet, Origin of Laws, etc., vol. i. p. 283.
[3] Phillips and Darlington, Records of Mining, etc., p. 14.

method of debasing the coinage. Lead was used to debase the coinage of China, if we may accept the statements of a recent writer, who says that in 585 Souy-Wen-Ty forbade the working of the tin and lead mines, in order to stop counterfeiting; and in 922 Héou-Tchang had all the counterfeit pieces of money, lead or tin, hunted up, even among private individuals.[1]

Polycrates is said to have coined a great many pieces of lead, cased with gold, to simulate the currency of the country.[2] Hannibal practised a similar deception on the people of Gortyna, in Crete. After the defeat of Antiochus by the Romans Hannibal retired to Gortyna, carrying with him immense treasures. To allay the excitement and envy which the possession of so great riches created, he pretended to deposit them in the temple of Diana, and with much pomp and display conveyed thither several vessels filled with lead.[3]

The Roman coin denarius was of silver, but a writer in a British journal mentions the discovery in England of a denarius made of lead, indicating perhaps that during the Roman occupation of that country the coinage was counterfeited.[4] Many leaden coins have been found in Italy. Some authorities consider them to be of Roman origin, though upon some Egyptian divinities are represented, and others bear Greek inscriptions. They are generally referred to the time of the emperors.

Lead was an important production in Greece in ancient times. Pythocles recommended that the State should monopolize the product of the mines, raise the price threefold, and thus increase the revenues. At this time the value of lead was about a half a cent per pound. In 407

[1] Biot, in Journal Asiatique, quoted by Bapst in L'Étain, p. 22, note.

[2] Herodotus, vol. i. p. 154.

[3] Ibid., vol. ii. p. 154.

[4] Archæological Journal of the British Archæological Association, vol. xvi. p. 212.

B. C. the price is said to have been a cent and a quarter per pound, and in the time of Pliny the cost of lead was about two and a quarter cents per pound.

Lead is found to be a component of the bronze used in ancient times in the manufacture of weapons and cutting instruments, and it is supposed that in these cases it was added to give toughness to the otherwise brittle alloy.[1] In casting statuary lead was frequently used in the lower parts to give greater stability. In some cases the core of the lower parts was of lead, covered with a thin plating of bronze. The addition of lead in the manufacture of bronze was almost universal in ancient times. The Egyptian bronzes are rich in lead. In some cases lead was added to impart some desirable quality to the alloy, in others to make it liquefy and cast more readily. Roman bronzes, mirrors, bell-handles, needles, sword-handles, statuary, etc., have notable quantities of lead in their composition. The addition of lead to bronze was at first made for practical reasons, but the quantity was finally increased and became a sophistication, which was made the subject of a decree in the third century, by the provisions of which bronze containing more than a certain quantity of lead became subject to confiscation.[2]

The oil-press is a very ancient mechanical contrivance. The old manufacturer provided uprights and cross-beams of great strength. The olives were put into stout wooden boxes, and were separated at intervals by perforated leaden plates.

Hoffmann thinks the ancient Greeks were occasionally unscrupulous at their games of chance. He infers from a statement of Aristotle that they sometimes played with dice loaded with lead.[3]

[1] Phillips and Darlington, Records of Mining, etc., p. 14. See also Daniel Wilson, LL.D., Prehistoric Man (London, 1876, 2 vols.), vol. i. p. 252.

[2] See Hoffmann, Das Blei, etc., p. 39.

[3] Ibid., p. 27.

The ancient navigators at first used bags of sand for anchors; sometimes stones with holes drilled through them to receive the rope answered the purpose. Frequently stones securely fastened in a stout wooden frame were used, such as may perhaps be seen to-day as part of the tackle of the dory of the shore-fisherman of the coast of Massachusetts Bay, where it is called a "killick." The Phoenicians used wooden anchors of this description, but instead of stones their anchors were provided with masses of lead to furnish the necessary weight. The anchors of the early Greeks consisted of large wooden pipes filled with lead. Diodorus relates that on the occasion of the first voyage of the Phoenicians to Spain they obtained more silver than their ships could carry and took the lead from their anchors and replaced it with silver.[1] The ends of the oars of ancient galleys were weighted with lead to secure a proper balance. Homer mentions lead, and refers to its characteristics when he says the point of Iphidamas's spear turned back like lead when it struck the silver shield,[2] and again when Iris plunged into the sea "she sank as sinks the ball of lead."[3] The apostle Paul refers to the use of lead in sounding in the sea, and Herodotus speaks of throwing the lead. Hoffmann refers to the story of Philetas, a teacher of Ptolemy Philadelphus, who was so thin his companions asserted he wore leaden soles to his shoes to prevent being overturned by the wind. Pliny says he saw a man named Athanatus dressed in a harness of lead weighing five hundred pounds, and wearing leaden sandals, walking about on a stage, thus showing his great strength. One of the methods of punishment adopted by the Greeks and Romans was to oblige the culprit to work for life in the mines with pieces of lead wound about his body.

[1] Diodorus, vol. i. p. 320.

[2] Iliad, Bryant's translation (Boston, 1875), book xi. line 280.

[3] Ibid., book xxiv. line 110.

Lead was used as plummets and as sinkers for nets at a very remote period. Pennant found in Wales, with other Roman remains, a leaden sinker, or plummet, of undoubted Roman origin, used probably for sinking a fish-net.[1] In the coat-of-arms of the Ancient Company of Plumbers of London the plummet occupies a conspicuous place. Beckmann contends that the plummet of the builder referred to in Zechariah was of lead, and not of tin as it is generally translated. He argues that lead would preferably be employed for such purposes on account of its greater weight, which would make it more suitable, and also on account of its greater abundance.[2]

The ancients ascribed many curious properties to lead. It was thought to be endowed with the power to make the pomegranate-trees bloom. This was effected, it was claimed, by encircling the trees with bands of lead. One of the oldest evidences we have of the use of lead is the discovery by Schliemann of pieces of the metal in the cities found by him buried under the débris of the mound at Hissarlik in the Troad. Schliemann found in the first buried city, with shapeless lumps of lead, articles of gold and silver and a bar of native copper, but no iron; and he directs attention to this latter fact as an evidence of the high antiquity of the most ancient city on Hissarlik.[3] In the second city he noticed neither silver nor lead, but gold and electrum were found, and he infers that lead was also known and was used.[4] In the third city in order from the bottom of the mound (the Homeric Troy, according to Schliemann) a curious leaden figure was found, which Schliemann classes

[1] Pennant, A Tour in Wales, vol. i. p. 74. Several leaden plummets are preserved in the British Museum, which were doubtless used by the Greeks and Romans for similar purposes.

[2] Beckmann, History of Inventions, etc., vol. ii. p. 208.

[3] Dr. Henry Schliemann, Illios: The City and Country of the Trojans (New York, 1881), p. 252.

[4] Ibid., p. 275.

as an idol. It was some three inches in height, with the features and attributes of a woman. It is suggested that it was intended to represent an Aphrodite.[1] Another leaden object found in the third city is in the form of an earring. If the Trojan war occurred so early as the twelfth or thirteenth century before Christ, and the mound at Hissarlik covers the ruins of Priam's city, these are the oldest manufactured objects of lead of which we have any knowledge. If Schliemann is wrong in his conjecture as to the identity of the buried city at Hissarlik with Homer's Troy, the importance of his investigations, so far as our subject is concerned, is but little impaired, as there can scarcely be a question as to the very great antiquity of the ruins uncovered by him.

In the fourth city a wheel of lead some four inches in diameter and provided with four spokes was discovered. This was perhaps a copy of the chariot-wheel of the period, and Schliemann suggests it may have been used as a votive offering. It recalls the leaden wheels preserved in the British Museum. Miniature wheels are not uncommon in the museums of Europe. They have been found, made of gold and of bronze, in the ruins of the Pfahlbauten of the Swiss lakes, and in the beds of streams in Europe. The early Grecian chariot-wheels were provided with but four spokes, and some of the wheels of the chariots represented in the Egyptian sculptures have but four.[2] In the fifth and sixth cities other leaden objects were found by the enthusiastic explorer; and in the seventh city, founded as Schliemann believes as early as 700 B. C., among other interesting objects discovered was a plate of lead some two and three quarter inches long and broad, ornamented with a boar's head in relief. This object may have been used as a weight or a coin.[3] The lead found in the earlier cities is

[1] Schliemann, Illios, p. 337. [2] Ibid., p. 565.
[3] Ibid., p. 620.

generally in shapeless pieces, and it was evidently but little used; but in the last, or the Greek city, the founding of which Schliemann ascribes to the sixth century B. C., it was in general use, and employed, as in the time of Vitruvius centuries later, as a means of holding in position the iron clamps used in uniting stones in building walls or other heavy structures.[1] Schliemann also found many objects of lead in excavating at Tiryns and at Mycenæ. At the latter place, among the treasures, was a vase in form of a stag, composed of a mixture of one third lead and two thirds silver; and another object composed of an alloy of silver with lead is described by him as a mouthpiece to a vase.[2]

The ruins of most Roman masonry show the use of lead for the purpose of securing the iron clamps which bind the stones. The great stone which closed the entrance to the mausoleum at Halicarnassus was firmly secured to its supports by bronze pegs, which were held in position by running in molten lead. This principle was observed with other structures. Cato recommends that the beams forming the uprights of the oil-mill should be first secured in position by wedges of willow wood, and then melted lead should be poured in to render the work firm and immovable. One of the first fruits of the expedition undertaken by the Archæological Institute of America to explore the site of the ancient city of Assos, in Asia Minor, was the discovery of the stump of an inscribed Doric shaft. This column was found *in situ* during the digging in 1882. The rock upon which it stood had been levelled off and cut to a broad base, in the centre of which a deep socket was cut of the same plan as the lower diameter of the shaft; into this socket the column was inserted, and retained securely in position by running in molten lead. Much of the

[1] Dr. H. Schliemann, Troy and its Remains (London, 1875), introduction, p. 32.
[2] Dr. H. Schliemann, Mycenæ (New York, 1878), pp. 77, 210, 257.

lead had been cut out by pillagers before the column was covered by the accumulating débris. The age of the shaft has been determined by the inscriptions which are engraved in two of the channels, and it is assigned to the sixth century B. C.[1] The stones of this ruined city were united by iron clamps, held in position by running in molten lead. Vitruvius recommends in building walls that they be two feet thick, preserving a middle space, and suggests strengthening the wall with clamps of iron run with lead.[2] Overbeck mentions a singular use of lead for architectural purposes discovered in the ruins of Pompeii. The brick walls of the atrium of one of the houses were found to be covered with sheet-lead, fastened to the brickwork by means of innumerable nails, whose projecting heads served to tie the stucco work with which the walls were afterward covered. It is supposed that the sheet-lead was added to prevent the absorption of moisture.[3]

Lead was also used in many cases where iron wire or iron or wooden hoops are used to-day. Wooden casks were sometimes furnished with leaden hoops, and the amphoræ used for storing water and wine were re-enforced with bands of lead. Broken amphoræ were repaired by means of leaden straps. Holes were bored in the parts, into which plugs of lead were run, the leaden hoops or straps were then put on, inside and out, and held in position by securing them to these leaden plugs. Lead was used for lids of vessels which it was desired to cover closely. Leaden wire found at Hissarlik, it has been suggested, was used by the women to fasten their hair, as fine iron wire is used to-day.

The Tirynthians were well acquainted with lead and its

[1] Joseph Thatcher Clark, in American Journal of Archæology, vol. ii. p. 268.

[2] The Architecture of Marcus Vitruvius Pollio, translated by Joseph Gwilt (London, 1839), p. 57.

[3] Dr. J. Overbeck, Pompeii (Leipzig, 1856), p. 242.

uses. Schliemann found several lumps of melted lead in the ruins of the ancient fortress, and a large piece representing the head and shoulders of a pig, besides several pieces of sheet-lead. This ancient people — their city was destroyed more than 460 years before Christ — used to repair their earthen vessels with lead. Several pieces of large vases and jars bound together with clamps of lead have been discovered, with some leaden clamps which Schliemann thought had served the same purpose.[1]

Lead has not been found in dredging on the sites of the ancient lake dwellings in the Swiss lakes, except as a component of the bronze which was largely used in the construction of domestic utensils and of arms. The small percentage of lead in the bronze is evidence that its presence is accidental, and can be accounted for only by assuming that it was an impurity in the copper. Iron has not been found in the ruins of the earlier stations, and silver is also absent in those ascribed by archæologists to the age of stone and of bronze, while gold frequently appears. It is probable therefore that Desor and Le Hon are correct in assuming that these metals were unknown to the builders of the pile dwellings of that age. Le Hon refers to the discovery, near Tifenau, of what he terms money of a very high antiquity made of *potin*, a mixture of lead and tin.[2]

From remote times lead cast in thin sheets or hammered into plates has been used to cover or to ornament furniture and armor, and to make tablets upon which to transcribe and thus preserve public acts and precious literary productions. Job prays that his words may be graven with an iron pen and lead in the rock forever.[3] Some writers ex-

[1] Schliemann, Tiryns, pp. 171, 172.

[2] E. Desor, Les Palafittes ou Constructions Lacrustes (Paris, 1865), pp. 72, 73; H. Le Hon, L'Homme Fossile en Europe (Bruxelles et Paris, 1877), pp. 245, 328.

[3] Job. xix. 24.

plain this to mean that he desired his works to be graven in the stone, and the incised portion filled with lead; and others that he intended they should be written with an iron pen or stylus upon tablets of lead.

The consul Hirtius, besieged in Modena, wrote upon a leaf of lead respecting his situation to Decius Brutus, who replied by the same method. Pausanias showed at the hippodrome a poem of Hesiod written upon sheets of lead. Pliny refers to public acts preserved upon leaves of this metal.[1] Some remarkable examples of the use of leaden tablets for this purpose are preserved in the British Museum. One plate of lead, beaten or hammered to about the thickness of a wafer, bears an inscription in Greek, apparently made with a sharp-pointed instrument of iron or other hard metal; another bears a Latin inscription, and is dated Rome, 738. One very thin lamina bears the following inscription in Latin: "By this Instrument, Charlemagne assumes the title of 'Occidentalis Imperialis,' etc., 801." Many of the letters in these plates still retain the thin scrapings of metal struck out by the stylus. Dr. Birch, from whose article on this subject in "Archæologia" the descriptions of the tablets in the British Museum are taken, is in doubt respecting their age, and thinks they may perhaps be referred to a much later time, the early part of the thirteenth century. In the ninth century the custom of writing precious matter upon metallic leaves prevailed. "Indeed," says Dr. Birch, "the custom does not seem to have failed from the classical period — when it was the fashion to inscribe maledictions upon leaden plates, afterwards deposited in some sacred precinct — until the time when George, Archbishop of Ravenna, appropriated a copy of the New Testament written upon leaves of gold."[2] In the Lawrence-Cesnola collection there are some leaden

[1] Pliny, Natural History, book xiii. chap. xxi.

[2] Archæologia, vol. xliv., article by Dr. Birch.

plates similar to those anciently deposited under the pavement of the temples and inscribed with imprecations. One has an inscription which indicates a very remote origin.[1] These imprecation-tablets were usually surreptitiously deposited in tombs, and sometimes even in the coffin of the deceased, that the curse might follow him to the other world. They were addressed generally to the gods of the lower regions, and seem to have been more frequently deposited by women than by men. The causes which led to this method of seeking vengeance seem to have been many and various. In one case a woman curses the person who made her lover untrue to her; in another a wife curses a slanderer, who said she intended to poison her husband; upon another tablet imprecations are directed against those who cheated by giving light weight; an unknown thief is cursed for stealing a bracelet; a wife cursed the maid who had tempted her husband to desert her and her children.

Leaden tablets were deposited at the temple of Jupiter, at Dodona, upon which petitions to the oracle were inscribed. These petitions asked replies to questions relating to political and to private affairs: the whereabouts of a mattress which had been stolen is anxiously inquired for; the sick ask what sacrifices to offer for the restoration of their health; tradespeople ask if their ventures will be successful, etc.[2] The word *plumbum* was sometimes used by the Romans to designate spouts or conductors of water. These pipes were usually made of lead, but in the villa of Antoninus Pius, at Lanurium, one of these conduits has been discovered a portion of which it is said is made of pure silver.[3]

Roman ruins everywhere show the care and expense be-

[1] Salamina, A. P. Di Cesnola (London, 1882), introduction by Dr. Birch.

[2] See Hoffmann, Das Blei, etc., p. 31.

[3] M. Rich, Dictionnaire des Antiquités, p. 272.

stowed by this people in their efforts to secure an abundant supply of pure and wholesome water. They sometimes used pipes of earthenware, but generally lead was the material employed in their manufacture. The leaden pipes were of fixed sizes, and they were designated by their calibre. In Pliny's time as many as fifteen different sizes were in common use. They were made by casting a sheet of lead of proper size, then bending it over a core and lapping the joint, which was hammered and firmly closed by soldering. They were made in regular lengths of about ten feet, and were from thirty to one hundred inches in circumference. The manufacturers of lead pipe, when casting the sheets, introduced into the table on which the molten lead was poured, or into the mould, objects which perhaps resembled modern type; thus when the sheets were cast there appeared upon them inscriptions, which generally referred to the date of manufacture, by giving the name of the consul then in power, or of the reigning emperor. Sometimes the name of a private person or of a company to whose order the pipe was made was introduced, and frequently the name of the manufacturer appears, as *ex officina Martini plumbarii.*

The enormous quantity of lead pipe discovered in Italy and in the provinces leads to the conclusion that the manufacture of this article must have been a most important branch of industry during the time of the emperors.

Vitruvius, referring to the water supply of large places, says: "Water is conducted in three ways, either in streams, by means of channels built to convey it, or in leaden pipes, or in earthen tubes. If the water is to be brought in leaden pipes a reservoir is first made near the spring, whence to the reservoir in the city pipes are laid proportioned to the quantity of water to be conveyed." Vitruvius describes with great care the method of laying the pipe, the proper fall to give to it, and suggests means to

overcome engineering difficulties.[1] The water from Mount Pila crossed three valleys through inverted syphons. The water was collected in a reservoir upon one hill and flowed through nine leaden pipes, each eight and a half inches in diameter and one and a half inches thick, down the hill to an arcade eighty feet high, which it crossed, and then ascended the hill on the other side, where it was collected in another reservoir. It has been estimated that the lead alone of this immense work would cost in modern times two millions of dollars.

Leaden pipes for conveying water were commonly used in early times. They have been found in the ruins of cities in Asia, in Egypt, and in Greece, at Herculaneum, and Pompeii. Sometimes pipes for this purpose were made of copper, stone, earthenware, wood, and even of leather, but lead was principally employed. Vitruvius says that the action of lead is deleterious, and that to secure wholesome water it should be brought through earthen pipes. He refers to the pallid color of the men who work in the lead-works, and says that the fumes from the molten lead destroy the vigor of the blood.[2] The ancients well understood the poisonous nature of lead; their writers frequently refer to it. Pausanias says that in the neighborhood of Puteoli there are hot springs, the water of which in a few years destroys the lead pipes through which it runs. The water was probably contaminated with hydrogen sulphide. Notwithstanding this knowledge of the deleterious effects of lead upon water the ancient Greeks and Romans used kettles, buckets, and other domestic utensils made of it.

The pipes used by the Romans were not always soldered at the joint; occasionally they were hammered together and closed by the blow-pipe flame, or by a cement. The joint of a leaden pipe of undoubted Roman manu-

[1] Vitruvius, p. 196.

[2] Ibid., p. 255.

facture, found at Uriconium, now Wroxeter, England, was closed with cement.[1] The ancients were acquainted with the art of soldering at a very early period. Mention has been made of the discovery, by Wilkinson, of examples of soldering in the tombs of ancient Egypt. Pliny gives elaborate instructions for soldering gold, copper, and lead. The latter, he says, "is united by the aid of white lead," meaning tin probably.[2] According to Livy, some men digging (in 183 B. C.) upon the farm of Lucius Petillius discovered two stone chests, the covers of which were soldered with lead.[3] The sling was one of the earliest weapons used in war. The Egyptian monuments in their decorations testify to its common use in the early days of that empire. The Israelites were skilled in the use of this primitive weapon. "Among all the people there were seven hundred chosen men left-handed; every one could sling stones at a hair's breadth and not miss."[4] The Greeks at first despised the weapon, but the troops of Xenophon, during their retreat from Asia, were so badly punished by the slingers of the Persian army that they adopted it; and they soon became more expert in its use than their teachers.

The slingers of the Egyptian and Persian armies in

[1] The Archæological Journal of the British Archæological Association, vol. xvi. p. 212.

[2] Pliny, Natural History, book xxxiii. chap. xxx.

[3] Titus Livius, History of Rome, translated by C. Edmonds (London, 1878), book xl. chap. xxix.

[4] Judges xx. 16; 1 Chronicles xii. 22. Strabo tells us that the natives of the Balearic Isles were especially noted for their skill with the sling, which they used with either hand. Their children were thoroughly practised in the use of this weapon. Their food was placed upon a high beam or the branch of a tree, and could only be enjoyed when it had been brought down with the sling. The Balearic slingers were efficient allies of the Carthaginians. They formed corps of about one thousand men each, and hurled their stones with such force and precision as to produce with them all the effect of musket-balls. Their stones crashed through armor and buckler, and were often the means of turning defeat into victory. See Strabo, Geography, book iii. chap. v.; also Heeren, Ancient Nations of Egypt, vol. i. p. 251.

ancient times went to the brook before a battle, and carefully selecting smooth stones of proper shape and size, filled the bag which every slinger carried suspended from his shoulder; but the art of war had so far progressed in the fifth century B. C. that the use of stones for such purposes had been superseded in the Grecian armies by leaden bullets. The sling-bullet of the Greek soldier was in shape something resembling an almond, elongated and conical at each end, thus giving greater range and precision, and showing that the advantage of this form of projectile was clearly understood at that early day. Stores of these bullets were kept in the arsenals for future use. Occasionally, however, the metal was transported with the advance stores of the army, and on the eve of an engagement the bullets were cast in the camp.[1] These leaden balls generally bore an inscription, in relief, indicating the division or corps of the army to which they were supplied, or the name of a famous general, or a device, such as a thunderbolt, a star, an arrow-head; or a telling inscription, such as "Appear," "Show yourself," "Desist," "Take this," "Strike Rome," and similar inscriptions and devices. They have been found on the plains of Marathon, Cephalonia, Ithaca, at Athens, and at other places. At Florence they have been found in such large numbers as to give rise to the suggestion that a Roman arsenal was formerly established there. These leaden bullets were made by casting in a stone mould. One stone usually had many perforations, or moulds, which seem to have been connected, as many bullets were made at one casting, and when taken from the mould they appeared like a bunch of grapes, each bullet having attached to it a little stem.[2] The Roman sling-bullets are less frequently found than the Greek, and the inscription in raised characters, which is generally found upon the

[1] Archæologia, vol. xxxii. [2] Ibid.

Greek bullet, is wanting on the Roman, or is limited to the number of the legion to which the soldier belonged.

Besides its use as a missile, the sling-bullet was frequently used to convey traitorous information to the defenders of a beleaguered place, or to the camp of the besiegers; and it was also used as a means of communication with a place otherwise inaccessible. These bullets generally weighed two to three ounces, though some were much heavier; they are frequently referred to by ancient writers, who testify to their efficiency in battle. A large and interesting collection of these curious objects is preserved in the British Museum.

In more modern times cannon-balls have been made of lead. In an inventory of munitions of war provided by the city of London against an expected invasion by the French in the reign of Edward III., this item occurs: "Also in the chamber of the Guildhall there are six instruments of latone (or latten) called *gonnes*, and five *roleres* to the same, also pellets of lead for the same instruments, which weigh 4 hundred weight and a half."[1] In the inventory of the keeper of the king's stores at Calais, in 1369, there appears the first mention of cannon-balls in the records of the British Government. This officer accounted for fifteen guns, three great guns, saltpetre, sulphur, gunpowder, and two hundred leaden balls.[2] In a collection of inventories occurs the following: "Inventour of the Artaileyeorie and Munitions with Plenissing, being within the castle of Edinburgh, 1566. Item: Certain Chanyeit bullettis of leid for battard, moyan and falcone. Item: Certain small bullettis and dyss of irne, serving to mak bullettis for moyane and cutthrottis."[3]

[1] G. A. Raikes, History of the Honourable Artillery Company (London, 1878), vol. i. p. 3.

[2] Archæologia, vol. xxxii. p. 379.

[3] A Collection of Inventories of Royal Wardrobe and Jewell Houses, and of

Lead was used in ancient times, in warfare, in other forms than that of the bullet of the slinger. Molten lead was thrown from the battlements of beleaguered places upon the heads of the assailants; and when battering rams were moved up to breach the walls, the defenders, by means of cranes, threw down upon them great masses of lead to crush and destroy them. According to Livy, the prætor Lucretius (in 173 B. C.) pushed the siege of Haliartus, in Boeotia, with great vigor; but when the ram was applied to the walls, the townsmen crushed it to the ground by dropping on it a mass of lead.[1] When the Romans attacked the city of Syracuse, Marcellus made the attack on the sea side, and advanced with a fleet of sixty vessels filled with soldiers armed with slings, bows, and javelins; and with eight vessels arranged to throw against the walls machines called "sackbuts," which were so contrived that when placed in position the soldiers from the top of them could attack the defenders; but when they attempted to raise them "Archimedes put in motion an engine of his own invention, which suddenly appeared above the walls, and stretching its long beak far beyond the battlements, dropped great masses of lead upon the sackbuts, breaking them and endangering the vessels and all on board."[2]

The Romans used a barbarous implement for the punishment of criminals, and for disciplining their slaves. It was a sort of whip like the *knout* of the Russians or the boatswain's cat formerly in use in the navy. Several chains were attached to a short handle, the end of each chain being furnished with a button of lead. With this instrument criminals and many of the early Christians were whipped to death. The gladiator pugilists fastened

Artillery and Munitions in some of the Royal Castles, 1488–1606. Edinburgh, 1815.

[1] Livy, book xlii. chap. lxiii.

[2] Polybius, vol. iii. p. 11.

leaden weights upon their knuckles to increase the force of their blows.[1]

Curious little leaden figures of nude women, some three or four inches high, of Greek or Roman origin, are preserved in some of the museums of Europe. These figures are provided with projections by which they can be suspended or made to stand upright. They are supposed to have been used in the temples; other leaden figures represent Diana. Hoffmann is of the opinion that they were used as similar leaden figures were some centuries later in Christian countries, as a souvenir of a visit to a holy shrine. Pilgrim signs were sold at Paphos and at Hierapolis, and at the Temple of Diana at Ephesus. The signs representing nude female figures may have had some connection with the cult of Venus. Leaden representations of cavalry soldiers of ancient origin are not uncommon in European museums. They have been considered to be children's toys, but may have been used as votive offerings. In the museum at Buda Pesth two leaden tablets are preserved, upon which are inscribed the details of the worship of Mithras.[2] Decorated leaden vases, Hoffmann says, are rare. He refers to a most beautiful specimen described and pictured by Overbeck in his masterly work on Pompeii. A number of interesting objects in lead, of ancient Grecian and Roman origin, are preserved in the British Museum,—rude figures of warriors, some three inches high, cavalry and foot soldiers, little leaden horses and dogs, and a leaden chair; these may have been used as children's toys, as toys of pewter and of lead were common in Rome at the time of the Empire. A number of leaden finger-rings, found in a tomb at Beneventum, an ancient city of southern Italy; a vase

[1] See Rich, Dictionnaire des Antiquités, p. 372; also Hoffman, Das Blei, etc., p. 24 *et seq.*

[2] See Hoffmann, Das Blei, etc., p. 18.

from a tomb at Halicarnassus; an elaborately decorated vase, some seven inches high, with figures in relief, representing the seasons, and with a circlet of colored glass or stone ornaments, found at Blacas; bracelets of lead; small vases or boxes, perhaps to contain eye-salve; a number of little leaden wheels, elaborately fashioned and decorated; plummets, sinkers, and custom-house seals; and plates of lead stamped with inscriptions, mentioned above, are also preserved there. A small bowl of lead about three inches in diameter, of undoubted Roman manufacture, was found at Uriconium.[1] Bapst quotes a description by the Abbé Martigny, of two curious objects in lead, of the period of the Roman Empire, which the Abbé thought were children's toys. They are imitations of the vases used in the church for exposing and elevating the Host.[2] In the museums at Moscow and at Berlin many curious leaden figures are preserved, including some leaden swine, the use of which is unknown.[3] The museum at York, England, is rich in Roman relics, among which may be noticed leaden coffins and ossuaries; a leaden weight dredged from the bed of the Ouse; lamps and candlesticks of lead, — all of Roman manufacture. There is preserved in the Cesnola collection in the New York Metropolitan Museum a miniature leaden table. It is ascribed to the time of the Roman republic, and may have been used as a votive offering.

Lead has been used through all historic times for purposes connected with the burial of the dead, for ossuaries, and for coffins, for bas reliefs and tablets commemorative of the virtues of the deceased; many ancient bas reliefs seem to represent the portrait of the person they are intended to commemorate. At Saida, in the ruins of Mara-

[1] See Archæological Journal of Archæological Institute of Great Britain and Ireland, vol. xvi., article by Phillips.

[2] L'Étain, par Germain Bapst (Paris, 1884), p. 44.

[3] Ibid., p. 45.

thus, an important city on the coast of Phoenicia, destroyed earlier than 150 B. C., leaden coffins have been found ornamented with curious inscriptions.[1] The ancient Greeks and Romans generally cremated their dead; accordingly ossuaries of lead are not uncommon in the burial-places of those countries. These mortuary urns were either cylindrical in form or shaped like ordinary pottery. In some cases the leaden urns were decorated with elaborate designs in relief, or were covered with inscriptions. They have been found in great numbers in Italy, in ancient Gaul, in England, and in other countries of Europe; and many are preserved in European museums. When discovered they frequently contained calcined bones, and in all cases the contents or surroundings were such as to leave no doubt as to the purposes for which they were used. Tylor remarks upon the methods employed in the manufacture of some of the leaden funeral vases found in England, and concludes that the lead was first cast flat, in sheets, then bent round into cylinders, the edges being joined with the blow-pipe without solder. The Romans understood perfectly the art of casting, and the use of the blow-pipe. One of the coffins examined by Tylor had cast upon it the decoration known as the "reel pattern," so placed as to act as a support, or rib; it was, moreover, cast hollow in order to save metal; its position strengthened the flat top and sides of the coffin; another had an eight-rayed star cast on the inside of the flat bottom.[2]

Leaden coffins have been found in France, Italy, and in Belgium, but none have been discovered in Greece, and of those found in continental Europe but few, it is thought, date so far back as the first two or three centuries of our era. In England, however, the custom of burying the dead in coffins of imperishable materials generally pre-

[1] Bapst, L'Etain, quoting Renan's Mission de Phénicie, p. 45.
[2] Archæologia, vol. xlviii. p. 221.

vailed during Roman occupation, — possibly, it has been suggested, because the material was very abundant and cheap. Hundreds of leaden coffins of Roman origin have been found in London, Kent, Wilts, Gloucestershire, Yorkshire, and in other districts during the past century, and Smith remarks: "There is no reason why this disinterment may not have gone on for a thousand years or more, and there are doubtless many yet buried which will never be disturbed." [1] Some of these coffins are very elaborately decorated with circles, raised figures, and beaded lines in great variety, the escalop shell being prominent.

Hunt describes a Roman tomb discovered in Monmouthshire. It consisted of a stone chamber, in which was a huge stone coffin lined inside with sheet lead, fitting accurately all around, soldered at the corners, and covered with a plain oblong sheet of lead.[2] Many of the leaden coffins were less elaborate in their construction and ornamentation. They have been found made of two sheets, or pieces of lead, one bent so as to form the bottom and the two sides, the other forming the top and ends. Phillips describes one made of a single sheet of lead, cut and folded so as to form a simple chest, over which was placed a leaden cover.[3] They were often very heavy, and occasionally were of sufficient size to hold two and rarely three bodies. It was the custom, after the body had been placed in the coffin, to pour in calcium sulphate, which filled all the interstices and formed, after the decomposition of the body, a perfect cast. Several interesting examples of these casts may be seen in the museum at York, in England. The great weight of the gypsum made it necessary, in these cases, to support the yielding metal; the coffins were, therefore, frequently

[1] C. Roach Smith, Collectanea Antiqua (London, 1848), vol. vii.

[2] Hunt, British Mining, p. 37.

[3] John Phillips, Rivers, Mountains, and Sea Coast of Yorkshire, etc., p. 192.

strapped with lead, or were placed in thick stone or stout wooden boxes. Occasionally they were double, and one has been found which is estimated to weigh more than a ton.[1]

Leaden coffins have been exhumed in France, in which coins of Roman emperors have been found; these coffins bear a strong resemblance to those found in England, and are frequently elaborately decorated with raised figures; in one instance, these decorations are lions' heads, which appear to have been stamped with dies. The escalop shell, which is seen so frequently on the English coffins, is wanting in the decoration of continental coffins; that ornament appears to have been peculiar to England.

The Anglo-Saxons did not bury their dead in leaden coffins; but in later times lead was again used for such purposes. The coffins of Earl Warrene and his wife were made of lead precisely in the same fashion, and with the same decorations as those of the Romans.[2] Edward the Black Prince was buried in a leaden coffin; and the body of Richard II. was also "lapped in lede." Lardner relates the story of the disposition of the remains of Geoffrey Mandeville in the reign of Henry I.; dying under the curse of excommunication he could not be buried in consecrated ground, so some of the Knights Templar enclosed his body in a leaden coffin, and hung it upon a tree in an orchard of the old temple.[3]

Leaden weights of ancient Roman or Grecian origin are not uncommon in the museums of Europe; they are usually six-sided, and the denomination is indicated by lines or dots. The Greek weights have inscriptions representing the denomination of the weight, and also a raised figure like an armorial bearing which seems to indicate the town or district where it was issued or adopted. Steelyard weights are more rare, but Hoffmann mentions one in the collection of

[1] C. Roach Smith, Collectanea Antiqua, vol. iii.

[2] Ibid.

[3] Lardner's Cyclopædia, vol. iii. p. 62.

Herr Trau, of Vienna, which is in the form of a bust of the Emperor Titus; the core is made of lead, but it is thinly plated with bronze. A bronze ring is fastened to the head.[1]

A bust of a Bacchante formed of lead cased in bronze was found near Southampton, England. It is evidently of Roman manufacture and is supposed to have been the weight of a steelyard, as it weighs exactly eighty-three ounces, or eight Roman pounds. The eyes are of silver, the lips and nipples are of copper.[2] Leaden weights of one, two, and three ounces have been found in England near old Roman stations. It has been suggested that they were used in assaying the argentiferous ores.

Dr. Birch has expressed the opinion that the oldest known objects in lead are probably the Archaic weights of Athens, of the Aeginetian standard, which he attributes to the fifth century B. C.[3] The discoveries of Schliemann at Hissarlik, however, antedate these objects by many centuries. The leaden weights of Greece were replaced by those of stone or bronze.

It is the custom to-day with some merchants and manufacturers, especially in Europe, to affix a leaden seal to the cords or wire used to surround and secure the bales or boxes in which merchandise is packed, to prevent pilfering or tampering with their productions during transportation. The Romans used leaden seals for this purpose, and many have been found, some with the strings still attached. The strings were laid across the lead while it was in a molten condition; it was then stamped on one or both sides. These ancient seals are precisely like the leaden seals, or bullæ, which were affixed to Papal deeds. Leaden seals still attached to the strings which fastened the bandages of a Grecian mummy are preserved in the British Museum.

[1] Hoffmann, Das Blei, etc., p. 27.

[2] Archæologia, vol. 32.

[3] Birch, Introduction to "Salamina."

The Roman seals discovered in England have generally been found on the sites of Roman camps, and appear to have been used by the troops. It is said that under certain circumstances leaden seals were affixed to the necks of Roman soldiers, upon entering the military service.[1] Casts of a leaden seal which was supposed to have been the seal of Cœnwef, king of Mercia, who reigned about the year 800, were exhibited to the Archæological Society of England in 1847. It had probably been attached to some instrument in the manner of the seals appended to Papal bulls.[2]

The attachment of leaden seals to packages of merchandise at Custom Houses in modern times is a survival of methods practised by the Romans. During Roman occupation of Gaul merchandise for distribution in the country was not examined, but that destined for transportation beyond the frontier was sealed with a leaden seal; and it is supposed that the leaden seals found in the Saône bearing the number of a legion, the name of a merchant, or of a city or a town, were of this character.[3]

Leaden seals have been found inscribed with letters or numbers. These were probably used to affix to boxes, bales, or perhaps to amphoræ, possibly to indicate the quality and quantity of the contents. They were generally square, and many were pierced with holes that they might be more readily nailed or tied to the package they were intended to designate. Another form preserved in the museum at Athens bears Greek inscriptions and monograms, and consists of two small round disks of lead connected by a small strip. On one of the disks is a small projection which fits into a corresponding depression on the other. When the

[1] C. Roach Smith, Collectanea Antiqua vol. iii.

[2] Archæologia, vol. xxxii.

[3] Bapst thinks that objects of this nature dredged from the Sambré were merchants' marks. Bapst, L'Étain, p. 186. See also Pigeonneau, Histoire du Commerce de la France, vol. i. p. 43.

disks were pressed together they became permanently fastened or locked. These medals or seals are thought to have been used by the clothmakers to mark the quantity contained in their bales.[1] In the reign of Henry VII. of England the clothmakers were obliged by statute to use leaden seals to mark the length and quality of their manufactures.[2] Lead was also used for seals to verify instruments of writing instead of a signature. This custom prevailed not only for public documents, but also for private agreements and contracts. A merchant's seal affixed to a document had all the effect of a signature. Dr. Birch says: "The last appearance of lead in ancient art is in the bullæ or seals inscribed with monograms of the Byzantine empire, as late as or later than the fifth century." [3]

The Greeks and Romans used leaden medals and tokens in great numbers. The Greek tokens date after the conquest by Rome. The purpose of these tokens has not been definitely established. Some archæologists are of the opinion that they were issued by the collegia, or guilds, and were used as badges of membership, their display giving to the wearer certain rights and privileges not otherwise attainable. Most of the tokens, *tesseræ,* which have been found bear emblems which indicate some play or game at the amphitheatre, — crowned heroes, the trumpeter who gives the signal to begin the fight, representations of horses and chariots, pictures of gladiators, or of their helmets, or their laurel wreaths; deer, bulls, lions, bears, and other animals which fought or were slain in the amphitheatre. Masks, symbols of the play, are represented; sometimes the play itself is pictured. Others bore triumphal processions, or apotheoses of emperors, indicated

[1] Hoffmann, Das Blei, etc., p. 37.

[2] J. H. Burn, Descriptive Catalogue of London Traders, Tavern and Coffee House Tokens of Seventeenth Century (London, 1855), p. 157.

[3] Salamina, introduction by Dr. Birch.

by Mercury, or by some genius with a blazing torch, or an eagle crowned with a cypress wreath. Some of these *tesseræ* have triumphal celebrations pictured, in which case, suggests Hoffmann, they were possibly used to commemorate an important event. Some had pictures of emperors, and may have been used as invitations to the celebration; others bore short inscriptions to commemorate religious feasts and other gatherings. These tokens or medals were generally flat and circular in form, and the inscriptions were mostly on one side only, and were crudely fashioned. Sometimes, however, those having heads only were carefully made, and were inscribed on both sides. A few were stamped, but generally they were cast in a mould.

During the last century a leaden medal, stamped on both sides like a coin, was found inserted in a little excavation, evidently made for it, in the plinth of a large granite column near the forum at Rome. It was placed in the excavation before the column, which entirely covered and concealed it, was raised into position. Similar leaden medals have been found under other columns in Italy. When the designs upon these medals represented an emperor's head it is supposed that they indicated that the marble was to pass free of duty, or that it was to be used in the erection of an imperial building. Hoffmann quotes the story of a certain mason at Rome who was allowed in the last century to take a large fragment of yellow marble from the famous villa of Hadrian. Upon examining the stone, after it had been deposited at his house, he observed a small piece which seemed to be loose; upon lifting it he found it had been fastened to the block with cement, and that it covered a little excavation in the marble in which reposed a leaden medal bearing a representation of the head of Hadrian, and an inscription which was partly defaced.[1]

[1] See Hoffmann, Das Blei, etc., p. 36.

An account of the employment of lead by the ancients would be incomplete if we did not include its use in medicine. The Egyptians used it for this purpose, and Hippocrates, Galen, and Dioscorides treat of it. It was considered to be cold and moist, and cooling properties were attributed to it. It was thought to have much in its nature which was solidified by cold, hence its rapid liquefying when subjected to heat. "If we rub a fluid in a leaden mortar with a leaden pestle it will become cooler," Galen says, "because a kind of juice comes out of the lead which causes the coolness." Lead acetate is considered to be cooling in its nature to-day, and a solution of it is used as a soothing and cooling lotion. Salves and plasters were thought by the ancients to be more efficacious if made in leaden vessels. Lead was believed either to impart certain mystic properties to the salve or to bring something out of the ingredients, which under other circumstances would remain latent. Metallic lead was used after surgical operations to keep the wound from closing too quickly.[1] Pliny mentions many curious remedies derived from lead. "It is used," he says, "without any addition in medicine for the removal of scars; and prepared as a liniment, or an ingredient in plasters, for ulcers, and for the eyes, etc."[2] Paracelsus boasted that he could cure two hundred different diseases with lead. The most extraordinary use to which the metal was put in Pliny's time, perhaps, is that described by him as follows: "The Emperor Nero, for so the gods willed it, could never sing to the whole pitch of his voice unless he had a plate of lead upon his chest, — thus," says Pliny, "showing us one method of preserving the voice."[3]

[1] Hoffmann, Das Blei, etc., p. 42.

[2] Pliny, Natural History, book xxxiv. chap. l.

[3] Ibid.

CHAPTER VIII.

LEAD IN THE MIDDLE AGES.

THE disturbed condition of Europe during the centuries immediately following the fall of Rome, almost entirely prevented mining operations, and the supply of metals became nearly exhausted. Lead, being more widely distributed and more easily procured from its ores than other metals, was, upon the approach of a more peaceful condition of society, made to serve purposes for which it is not altogether suitable, and for which it has been superseded in our own times by other metals.

Mention has been made of the use of lead as money in very ancient times, and of the presence of lead in notable quantities in the early Greek and Roman coinage. About the beginning of our era lead almost entirely disappeared from the coinage of Greece and Rome; the small percentage found in coins of this period is probably due to the inability of the ancient metallurgist to secure a greater degree of purity in the noble metals. Lead reappears upon occasions in the coinage of the middle ages; several pieces of leaden money of this period are preserved in the British Museum. Counterfeit English money, made of lead and cased with silver, was coined in France in the thirteenth century.[1] James II. authorized the coinage of

[1] Macpherson, Annals of Commerce, vol. i. pp. 451, 463. During the latter part of the thirteenth century England was flooded with counterfeit money, and orders were issued to the coast-guard officers to prevent its importation from

tin, bronze, and pewter money, and it is said, of leaden money also. Erasmus mentions the currency of leaden money in England in his day, but these statements refer perhaps to the tradesmen's tokens, which will be noticed hereafter. Pieces of leaden money of the tenth or twelfth century have been found in France, but Bapst thinks they were used only as *monnaies d'appoint*, odd money, something thrown in to make a good bargain.[1] In exceptional cases — in times of war, or in a beleaguered city — the authorities have coined money of base metals, and occasionally certain persons have been privileged to do so; but these instances are rare, and the amount so coined and circulated has been inconsiderable. During the siege of Oudenarde, in 1582, pewter money was struck; and the canoness of Mauberge had the privilege of coining leaden money bearing the effigy of Saint Aldegonde.[2]

Medals or tokens dating from the eleventh to the fifteenth centuries have been found in great numbers in dredging and excavating in the beds of streams in France, in England, and in other European countries. These tokens generally bear some figure or device; they are usually without inscription, and have the appearance of coins, and may have served as money in exceptional cases. They are sometimes of tin or copper. In the time of John the Good, of France, they were made of leather, but they are generally of lead, and were made by casting in a mould.[3] Some were of a religious character, and were sold at shrines and at celebrated churches, as they

foreign countries. The measures taken were ineffectual, and the matter became so serious that the circulation of foreign money was forbidden, and all strangers coming into the country were obliged upon landing to exhibit their money for its examination by officers appointed for that purpose and stationed at the principal seaports. In 1299 all importers of counterfeit money were ordered to be put to death.

[1] Bapst, L'Étain, p. 178.

[2] Ibid., p. 180.

[3] Rigollot, Monnaies Inconnues, etc., quoted by Bapst, L'Étain, p. 179.

are to-day; some were issued by craftsmen and others, and bore their insignia; and some, in obedience to a custom which has persisted from very early times, were perhaps cast in honor of a great victory, to commemorate an important event or the presence of a distinguished individual, or for a political or other rallying sign.

M. Arthur Forgeais published, in 1862–66, a work describing and illustrating medals, tokens, and other articles of the same character found in dredging in the Seine, at Paris. M. Forgeais accounts for the presence of so large a number of these interesting objects in the bed of this stream by the fact that, in ancient times, the houses of the inhabitants were generally built directly upon the banks of the river, and that the bridges were lined with houses occupied by artisans and shopkeepers. The early bridges were built of wood, and were repeatedly destroyed by fire, ice, and flood, and the houses lining their sides shared, with their contents, the same fate. Objects of metal thrown into the river by these accidents would sink to the bottom and be preserved, while those of perishable material would be destroyed. These leaden antiquities have been found in greatest abundance in Paris near the Quai Notre Dame, in the vicinity of the shops and stalls of the principal artisans and toy-sellers of the time, and of the principal seat of the manufacture of these wares. It has been suggested also that the presence of these objects in the bed of the Seine, and of other rivers, may be accounted for by the persistence to a comparatively late date of the ancient custom of throwing coins or money into the streams.

The Corporations or Trade Guilds of Paris were established at a very early period.[1]

[1] These corporations were the legitimate successors of similar societies of the Gauls under Roman rule, which were modifications of the societies, called *Collegia*, of the Romans, which in turn perhaps had their origin in the associ-

The corporation of the Pâtissiers of Paris existed as early as 1060, the Plombiers-Couvreurs were incorporated earlier than 1648, as at that time laws existed under which they could qualify as Maîtres Plombiers-Fontainiers. Their work was always stamped with the first two letters of the name of the master plumber under whose supervision it was executed. The apprenticeship lasted six years; the cost of a membership was sixty livres, that of a mastership one thousand five hundred.[1]

In the fifteenth, sixteenth, and seventeenth centuries medals and tokens were issued in great numbers by the trade guilds of Paris. These tokens were generally of lead, were circular in form, and were made by casting in a mould of slate, many of which have been found by Forgeais in the Seine, at Paris. The tokens were probably used for various purposes; in some cases they were given to a member upon his admission to a guild, as a sign of his enrolment; in

ations of the Greeks called *Eranio* or *Thiasoi*, which flourished in the third century B. C., notably at Rhodes. The Grecian societies were more nearly like the craft guilds in the middle ages than the Roman *Collegia*, as their members contributed to a general fund, aided one another in distress, provided for funerals, and met in assembly to deliberate upon their affairs. Violations of their rules were punished by fines, and he who failed to pay his dues was expelled. The watermen of the Rhone, Saône, and of other rivers in Gaul had their societies, called *Collegia*. The remains of an altar, erected by the watermen of the Seine, was found under the choir of Notre Dame in 1711. Tradesmen and shopkeepers formed similar societies, which were succeeded in the eleventh and twelfth centuries by the trade corporations, some of which exist to-day. These corporations were very powerful in the thirteenth and following centuries. The members of a craft were generally grouped together, sometimes occupying one street, to which they gave the name. They had their rules and regulations defining the rights and duties of masters, craftsmen, and apprentices, their committees to defend their privileges, and halls or places of meeting. Members had the assurance of assistance in distress, the dead were buried, prayers offered for the repose of their souls, and the orphans, the old, and the infirm were cared for and protected.

See H. Pigeonneau, Histoire du Commerce de la France, première part, pp. 123, 234.

[1] Arthur Forgeais, Collection de Plombs Historiés trouvées dans la Seine, etc. (Paris, 1862–66), première série, p. 105.

others, perhaps, as an evidence of membership, to secure certain privileges pertaining only to a member. The tokens generally bore on the obverse side a representation of the patron saint of the guild, or of his insignia, and upon the reverse the tools appertaining to the craft. The religious aspect is rarely or never found wanting, and frequently appears upon both sides.[1] The leaden token of the Paris plumber is described by Forgeais, from a seventeenth-century specimen found in 1859 in the Seine, as follows: "On the obverse side appears the Holy Trinity, — God the Father, supporting the arms of the cross which bears the body of Christ, and the Holy Dove, which is seen escaping from the mouth of the Father. On the reverse, the tools of the craft: a soldering-iron, a hatchet with a pointed head, and an ingot or pig of lead."[2] The prevalence of the custom of circulating tradesmen's tokens in France in the fifteenth, sixteenth, and seventeenth centuries is indicated by the discovery by Forgeais in the Seine at Paris of medals representing no less than fifty tradesmen's and mechanic's guilds. Nearly all the mechanic arts are represented, together with the booksellers, the wine-merchants, fish-dealers, and other shop-keepers.

Under the head of medals and tokens Bapst classes the leaden imitation money, *monnaies des innocents,* thrown among the people at the fêtes, and he suggests that the tokens found by Forgeais decorated with a single letter in relief, and for the use or purpose of which Forgeais acknowledges he can find no clue, were possibly children's playthings, and served to teach them to read,[3] like the box of blocks used for similar purposes to-day.

It is possible to assign some use for most of the tokens found in England and France, but in some cases it is

[1] See Bapst, L'Étain ; also Forgeais, Collection de Plombs, etc.
[2] Forgeais, Collection de Plombs, etc., première série, p. 105.
[3] Bapst, L'Étain, pp. 182, 184.

utterly impossible to conjecture for what purpose they were circulated. This is especially true of large numbers which bear reproductions of erotic designs; sometimes it is a phallus, and more frequently the external female genitalia. These have been dredged in great numbers, especially the latter, from the bed of the Seine at Paris; and with them many moulds of slate representing the same subjects have been found, in which objects of this nature have probably been cast. Forgeais is unable to offer a wholly satisfactory suggestion as to the purpose of these medals, and laments that there exists no explanation or even reference to them in the literature of the period when they existed in great numbers; for it is a curious fact that although very many have been found, *no two are alike,* and as one mould would serve for casting many specimens, the number in use must have been enormous. These erotic medals were frequently provided with a pin at the back, to enable the owner to wear it as a brooch; others have a ring at the top, and could be suspended by a string from the neck; the larger number, however, of those represented in Forgeais's illustrations were unprovided with these accessories. Those found by Forgeais are attributed by him to the end of the fifteenth or the beginning of the sixteenth centuries.[1] Emblems of this character were worn in ancient times as amulets or charms; Pennant found near Flint, in Wales, an amulet of lead in the shape of a heart, upon which erotic designs were displayed. He considered it to be of undoubted Roman origin.[2] The custom of wearing charms as a protection against sickness, malignant demons, and the evil eye, has persisted from a remote antiquity. The scarabæus of the Egyptians was an amulet and in the Atharva Veda lead is mentioned as being used as a charm against the evil eye. Amulets of erotic de-

[1] Forgeais, Collection de Plombs, etc., extra series; also Bapst, L'Étain, p. 184.
[2] Pennant, A Tour in Wales, vol. i. p. 73.

sign were worn in the ninth century as a protection against evil spirits, and it is said that in Italy they are hung upon the necks of infants to-day to protect them from the baleful effects of the evil eye. Forgeais suggests that the erotic medals found in the Seine may have been used as charms or amulets of this character.[1] The creative powers of nature have been worshipped in many countries, and it has been suggested that these tokens may show the persistence of some ancient rite or custom connected, perhaps, with phallic worship. These erotic medals ceased to be used after the fifteenth century.

In the time of the Crusades it was the custom for the crusader and the pilgrim to the Holy Land to gather a shell on the shores of the Mediterranean, and to fasten it to his cloak as an ornament, and as an evidence of his pilgrimage. Godfrey de Bouillon is said to have been so decorated when he stormed the citadel of Jerusalem. This custom soon became general, and the escalop shell was adopted as the badge of several orders of knighthood, and of pilgrims to all holy shrines, and it is found in the armorial bearings of many old English families. The natural shell was soon replaced by a leaden reproduction, which in its turn was superseded by little leaden images of saints, which were often accompanied by a formula or legend.

The earliest written mention of these badges, according to Bapst, was in 1183, when the sign consisted of an image of the Virgin.[2] After this time the use of these badges increased rapidly; they were produced in great numbers, and were sold by the attendants at shrines in every Christian country. Every saint in the calendar was honored by the reproduction of his figure or his attributes on a leaden medal. The dress of the saint varied from

[1] Forgeais, Collection de Plombs, etc., extra series.
[2] Bapst, L'Étain, p. 188.

time to time as the fashions of the period changed. Each country had its favorite saint. In England, during the Crusades, Saint Thomas à Becket, of Canterbury, was most venerated, and many signs bearing his effigy have been found in England. In the north of France Saint Denis was the patron saint until the accession of the Valois to the throne, when Saint Michel replaced him. In other parts of France Saint Nicholas is represented on the signs. Saint John the Baptist was also frequently honored in this manner, especially in England.

These images were sometimes made of tin or pewter, but they were generally of lead. Forgeais describes and illustrates with minute detail very many pilgrim signs found in the Seine, representing many shrines, and dating from the thirteenth to the sixteenth centuries; each was provided with a hook at the back to enable the wearer to fasten it to his garment. They were evidently preserved with great care, and were generally worn as evidence of a visit to a holy shrine, though in the disturbed condition of society in the middle ages it is probable they also served as a passport or safe conduct to the wearer.[1] It was also customary to wear them in the hat. Louis XI. wore a number of these leaden images affixed to his hat, and upon occasions of great moment took it off, knelt before it, and prayed for the intercession of the saints whose effigies were represented by these leaden figures.

The manufacture and sale of these pilgrim signs were monopolized for many years by the monks and sacristans of churches and shrines, who found it a fruitful source of revenue.[2]

In addition to the pilgrim signs and tokens dredged by

[1] Forgeais, Collection de Plombs, etc., troisième série, p. 6.

[2] In ancient times silver tokens were sold at the Temple of Diana at Ephesus to the worshippers, who preserved them as a souvenir of their pilgrimage.

Forgeais from the Seine, he found medals and tokens of other kinds, which he illustrates and describes in his sumptuous work, — ecclesiastical medals, which bear inscriptions relating to the service of the church; ampulæ intended to represent the sacred vessel which holds the chrism; medals bearing representations of shields, carrying frequently the escutcheon of France. These specimens it is thought were used as tickets of admission to royal entertainments or to the palace. Others bear the arms of Navarre, Champagne, or of other districts, or of noble families, and were possibly used as *jetons* to throw to the people on festal or on other occasions, or were used to give safe conduct or admission to the apartments, or to the presence of the individual whose arms are depicted on the medal. Other medals illustrated by Forgeais were issued by tradesmen, and were used as tokens when small change was scarce; some perhaps served as checks to mark the days or hours of work performed by laborers. Forgeais illustrates a type of medal bearing a representation of a human head, sometimes grotesque, but he omits to give a satisfactory explanation of the use of these curious objects. Other medals were used perhaps as a warrant to keep a stall in the market, or a toll-gate, as evidence of permission to ask alms, or to receive from the poor fund a small sum of money, or its equivalent in food, like the modern "soup-ticket." Examples are mentioned bearing the insignia of officers of the king's or the queen's household; others were used as rallying-signs, and forcibly remind one of the medals circulated during the period immediately preceding a presidential election. Some were made in imitation of the currency of the period; others bore representations of crucifixes, animals, flowers, and other objects in great numbers and in great variety. Forgeais found with these medals many examples of the moulds in which they had been cast. They were usually

made of slate or of other hard stone, were generally well executed, and arranged to be held firmly in position during the operation of casting by a dowel-pin.[1]

Previous to the reign of Edward III., all associations of craftsmen which existed in England were simply licensed, but during this reign (1327–77) a law was enacted providing that "all artificers and people of mysteries should each choose his own mystery before the next Candlemas Day, and that having chosen his mystery he should henceforth practise or use no other." Some of the guilds were now incorporated, and soon proved to be powerful factors in public affairs. At one time no less than forty-eight corporations sent members to the common council of London.[2] Their rules for the preservation of the secrets of the craft were very precise and were rigidly enforced. Members were enjoined not to go abroad to teach the mystery of their craft, nor to take as an apprentice the son of an alien.[3]

The Plumbers Company of London existed as an association for very many years before its formal incorporation, which occurred in the ninth year of James I. (April 12, 1611). The earliest mention in England of the term "plumber" noticed occurs in a memorandum of the cost of a new font at East Deereham, Norfolk, dated 1468, in which is found the following item: "Paid William, the plumber, for leading the new font, 2^s 6^d."

In the act of incorporation the company is styled "The Master, Wardens, and Commonalty of the Mysteries of Plumbers of the city of London." They adopted a coat-of-arms, which is described as follows: "Ón a chevron

[1] See Forgeais, Collection de Plombs, etc., cinquième série.

[2] Charles Knight (London), vol. v. pp. 125–127.

[3] Wm. Maitland, F.R.S., The History of London from the Foundation by the Romans to the Present Time (London, 1739), p. 699. The ancient Egyptian artificers were prohibited from following any other trade than their own, and could take as apprentices only their own sons.

between, in chief two plummets, and in base a level reversed, two soldering-irons in saltire between a cutting knife on the dexter and a share-hook on the sinister, in chief a cross-staff fessewise," with the motto, "In God is all our hope."[1]

In the year 1619, or thereabouts, the Company of Plumbers petitioned to the king, alleging that "there was great deceit and falsifying in the casting and making of pigs and sows of lead, by putting in lumps of cinders, dross, and other scum, to the great loss and hindrance, and to the disgrace of the commodity beyond seas," and praying that an officer be appointed "to attend at the smelting-houses, and seal the same, to discover the good from the bad." Notwithstanding a furious opposition, the Plumbers had sufficient influence to secure the appointment of an inspector for a period of thirty-one years, who was allowed, as fees, 2*d.* per hundred weight. The incumbent resigned after a year or two, and his successor was never appointed.[2]

The plumbers were a flourishing corporation for many years, and built a small but neat building called "Plumbers Hall" in a place formerly called "Chequer Yard." In 1770 an historian of London informs us it was used as a dancing-school.[3]

The painters' corporation existed as a fraternity in the time of Edward III., but their first charter was granted by Edward IV., in 1470. In this charter they are styled "Peyntours." They were afterwards called "Painters-Stainers," and under this name were incorporated by Elizabeth, July 19, 1582. At this time the Painters-Stainers "were charged with the setting forth of twelve soldiers

[1] Maitland, History of London, p. 609.

[2] Analytical Index to the Series of Records known as "The Remembrancia," preserved among the archives of the city of London. Privately printed for the city of London, 1878.

[3] Noorthoack, History of London (London, 1773), p. 613.

with all their furniture."[1] The name Painters-Stainers arose from the fact that at that time a picture painted upon canvas was styled "a stained cloth," as one on a panel of wood — which was the usual foundation for a picture in early times — was called a "table," — possibly, it has been suggested, from the French word *tableau*. In the inventory of pictures of Henry VIII. appears the following: "Item: one table, with the picture of the Duchess of Milan, being her whole stature. Item: one cloth stained, with Phebus rideing with his cart in the air, with the history of him."[2]

In the list of corporations the Painters-Stainers were No. 28 in precedence, and they soon became rich and powerful. They built a hall on the west side of Trinity Lane, and adorned it with screens and arches, and decorated its walls with many fine pictures and portraits.[3] They claimed, Knight says, a supervision over the highest branches of art, and Kneller, Reynolds, and other great English painters were proud to be enrolled among the members of the guild.[4]

The small coinage of England in early times was of silver only; consequently transactions requiring very small change were carried on by means of base foreign money and English leaden tokens. In the early part of the middle ages but few persons could read, and merchants, tradesmen, and artisans adopted insignia to distinguish their shops and their merchandise. Taverns were also distinguished by peculiar signs. Some of the earlier of these devices were of a religious character; later they were of a loyal or popular form. Tradesmen and tavern-keepers feeling

[1] Walter Thornbury, Old and New London (London, 1881, 6 vols.), vol. ii. p. 37.

[2] Horace Walpole, Anecdotes of Painting in England (London, 1876, 3 vols.), vol. i. p. 63.

[3] Noorthoack, History of London, p. 613.

[4] Knight, London, vol. v. p. 127.

the need of small money issued their tokens, which were of brass, pewter, and frequently of lead, and bore as a device the sign adopted to distinguish their trade, shop, or tavern.[1] In an account-book of Nicholas Ball, marketman, of Chudleigh, Devon, under the head of expenses, appears the following: "Item: P'd for a nyron with a prynt and for lead and for smytyng of my tokens iij^{s}."

The issuance of these leaden tokens, notwithstanding their illegality, and that laws were frequently passed forbidding their circulation, persisted for more than a hundred years. At first their circulation was a very great convenience, but they soon became a source of trouble and embarrassment; for the profit arising from the custom was so enticing that many cities and towns, in their corporate capacity, issued tokens made of base metals. The cities of Bristol, Oxford, and Worcester struck leaden tokens for currency in the beginning of the seventeenth century. According to Evelyn, every tradesman had his leaden token. It is estimated that at this period the tradesmen of London alone issued leaden tokens amounting to as much as £15,000 annually. While in the catalogues of Burn and Boyne nearly every trade and craft is represented in the devices on the tokens described, and the arms of the trade-guilds are constantly met with, the Plumbers and Painters-Stainers do not appear, either in the tradesmen's signs or in the arms of the corporations stamped upon the tokens. Possibly in practice seveial crafts were united in one person, as they are to-day in many cases in England, where the plumber is also house-painter, gasfitter, and general decorator.

In 1609 Sir Robert Cotton urged the government to issue brass or copper small money, and in 1613 the king, James I., granted to John, Baron Harington, for a consideration, the privilege of coining brass farthings. The new

[1] Boyne, Tokens Issued in the Seventeenth Century, etc., p. 18.

currency was soon counterfeited, and in 1633 a law was enacted forbidding the counterfeiting of farthings.[1]

In the middle ages the costume required a girdle to secure the tunic at the waist. These girdles were fastened by metallic buckles; enormous buckles were also worn on the shoes. The buckles of the middle and lower classes were generally of lead or pewter, but tradesmen soon emulated their superiors and wore buckles made of silver. In the time of Edward III. a law was enacted forbidding the wearing of silver buckles by tradesmen and yeomen.[2]

The custom of burying with the dead domestic utensils, weapons, food, and other objects which it was thought would be useful to the deceased in a future life, has generally prevailed with primitive peoples, and has persisted in some cases even after an advanced state of civilization has been reached. Reproductions in lead of domestic utensils, knives, tripods, candlesticks, etc., of too fragile a nature for use, and evidently mere imitations, have been found in ancient sepulchres in Italy.[3]

In the early days of the church it was the custom to inclose in the coffins of the faithful reproductions of symbolic objects, the originals being generally made of more precious metals. A leaden chalice found in a tomb and preserved at Rome is ascribed to the third century. It is elaborately ornamented on the circumference and in the centre with Christian symbols. In the centre of the disk the sacrifice of Abraham is represented; other Biblical subjects are depicted around the circle. Two leaden chal-

[1] See Burn, Descriptive Catalogue of London Traders, Tavern, and Coffee House Tokens, etc.; also Boyne, Tokens Issued in the Seventeenth Century, etc. At a General Court held in Newtown (Cambridge, Mass.) brass farthings were forbidden to be circulated, and leaden bullets were made to pass for farthings.

[2] C. Roach Smith, Collectanca Antiqua, vol. i.

[3] The leaden objects preserved in the museums of Europe, representing in miniature chairs, tables, horses, wheels, and other articles in common use, were perhaps deposited in tombs in obedience to this custom.

ices preserved in the museum at Amiens are referred to by Bapst as unique on account of their form, which differs from that usual in the middle ages, as well as of the material employed. The Abbé Cochet found in the sepulchres one made of lead, and one of the same form has been discovered near the body of a man buried near Salisbury, England.[1] The Bishop of Angiers, who died in 1290, was buried in a rich coffin with a cross of copper or tin by his side, and upon his breast was placed a leaden chalice provided with a paten of the same metal. In a tomb at Fécamp, of an abbot who lived in the eleventh century, a little leaden cross has been found, and in the cabinet of the present proprietor of the Abbey of Jumièges there are preserved three abbot's-staffs made of lead of the eleventh to the thirteenth centuries, and a leaden sword-scabbard, which were found in tombs within the precincts of the abbey. One of the staffs is said to have been from the tomb of Thierry, second abbot, who lived early in the eleventh century.

Lead may have been employed in the manufacture of sacred vessels for the church in early days, as its use for such purposes was interdicted in the middle of the seventeenth century. The Cardinal de Lugo wrote in 1652, "The chalices used in churches are almost always of bronze or gilded copper; the reason why gold and silver and tin are retained, and other materials are proscribed, is that wood, stone, and ivory, being porous, absorb a portion of the consecrated material; glass breaks easily; copper, bronze, and lead often take by contact with wine an oxidation, which decomposes certain parts, and can, by charging the liquid, produce sickness or disgust."[2]

As in earlier times, lead was used in the middle ages to rule fine lines on parchment designed to be written upon,

[1] Archæologia, vol. xxxvi., article by Ackerman.
[2] See Bapst, L'Étain, pp. 93, 104, 105, 137.

when it was desired that the work should be particularly regular and elegant. The lead was not used in the form of a stylus or pencil, but in thin round plates, which would not cut the parchment or bend easily. Some old manuscripts preserved in the British Museum show very clearly to this day these fine lines.

Lead has been used from very early times for inlaying in wood, and in metals, and for ornamenting furniture, armor, and horse equipments. Articles of gold, silver, electrum, and bronze, inlaid with lead, also iron weights overlaid with lead or bronze, have been found in burial-mounds in Norway, Sweden, and in Denmark, dating, it is supposed, to the beginning of the eleventh century.[1] Moore mentions the discovery of ancient scales, with balances made of a mixture of copper and lead.[2] In France, from the time of Louis IX. to Francis I., the beams and joists of the apartments of the royal palace were ornamented with an alloy consisting principally of lead, cast in figures and richly gilded, representing "fleur de lis."

The use of lead in ancient times for conduits for water has been referred to. In 1285 pipes of lead were laid in Cheapside, London, for supplying the city with water brought from Paddington. Cardinal Wolsey, at a later period, caused more than eight miles of leaden pipe to be laid for supplying water to his palace at Hampton Court.

Lead appears to have been used in the eighth century for a purpose unknown in our time, as leaden beads were recently found in excavating in an Anglo-Saxon cemetery in the Isle of Wight.[3]

The mirrors of the ancients were made of stone or metal. Silver, copper, or an alloy of copper with other metals, were used by the ancient Greeks and Romans. Ac-

[1] Earl of Ellesmere, Guide to Northern Archæology, p. 55.

[2] Moore, Ancient Mineralogy, p. 62.

[3] Archæological Journal British Archæological Association, vol. xxiii.

cording to Pliny, the ancient Romans first used an alloy of stannum and copper, and the best were made at Brundisium. The stannum referred to by Pliny was probably tin, though Roman mirrors made of mixed metals frequently contained lead, and the stannum mentioned by Pliny may have been argentiferous lead. Silver, in Pliny's time, was preferred; but this, he says, "has been corrupted by the devices of fraud." According to Beckmann, the first mention of glass mirrors was in a work published in 1279.[1] At this time, and for a long time subsequently, the backs of mirrors were covered with lead to serve instead of quicksilver for the reflecting surface.[2] Percy mentions having seen at Birmingham glass buttons coated with lead at the back to give them a bright reflecting surface, and he describes the process in detail. The same method was formerly adopted in making cheap lamp-reflectors, in which the general contour of the concave metallic surface is preserved by setting the glass in small pieces. This process is also used to-day in backing cheap looking-glasses.

Lead was used in the manufacture of glass in very early times. Schliemann found at Spata, in Greece, great numbers of small ornaments, which proved upon analysis to be of glass which contained a large percentage of lead. These objects appeared to have been cast in moulds, and were provided with holes or rings to enable the owner, Schliemann suggests, to fasten them upon his garment. He ascribes to Spata a great antiquity, perhaps as early as the eighth century B. C.[3] Eraclius, in the ninth or tenth century, describes the manufacture of glass. He says: "Take good and shining lead and put it into

[1] Pliny, Natural History, book xxxiii. chap. xlv; ibid., book xxxvii. chap. v.; also Beckmann, History of Inventions, etc., vol. ii. p. 68 *et seq.*

[2] Beckmann, History of Inventions, etc., vol. ii. p. 76; see also Kopp, Geschichte der Chemie.

[3] Schliemann, Mycenæ, introduction, p. 45.

a new jar and burn it in the fire until it is reduced to powder, then take it away from the fire to cool; afterwards take sand and mix with that powder, but so that two parts may be of lead and the third of sand, and put it in an earthen vase. Then do as before directed for making glass."[1] Beckmann notices an ancient mirror which is said to have belonged to Virgil, and which has been preserved among the antiquities at St. Denis from an early period. This mirror was accidentally broken, and an analysis of some of the fragments showed that a considerable quantity of lead was used in the manufacture of the glass.[2]

Before the thirteenth century the conveniences of the table were of the most primitive description. A man and his wife ate from the same wooden platter, and but few households possessed more than two or three drinking cups. The joint was brought on in a wooden trencher, and was passed to each guest in turn, who, taking his knife from his girdle, cut off such parts as he wished. After this period, however, the increase of wealth and power induced in the higher classes more luxurious habits and a more ostentatious manner of living. As silver was far from abundant, the nobles and the wealthier classes were forced to use a less rare metal for articles of table furniture, or continue to share with their servants the wooden trenchers, which for many years remained the only species of platter used by the lower classes.[3]

When pewter vessels were introduced, it is impossible to say. Some think the first manufacture of pewter was perhaps coeval with the working of the tin and lead mines of England; but according to Hunt, latten ware, or

[1] Eraclius, De Coloribus et Artibus Romanorum, translated by Mrs. Merrifield in Original Treatises on the Art of Painting (London, 1849, 2 vols.) vol. i. p. 216.

[2] Beckmann, History of Inventions, etc., vol. ii. p. 76, note.

[3] Hallam, Middle Ages, vol. iii. p. 323.

pewter, came into general use in the fifteenth century,[1] but the manufacture had become so important in 1474 that the pewterers of London were incorporated by an act of Edward IV.

Pewter is a compound of tin and copper, to which lead is added in variable amounts. In some countries the amount of lead in the alloy is prescribed by law. In the ordinances and rules of the tin-pot makers of Nuremberg, who were celebrated throughout Germany for their wares, they are forbidden to add more than one pound of lead to ten pounds of tin. In France the word *étain* means pewter as well as tin, and *étain mort* is used to designate pewter in which lead forms a notable part of the alloy. The Abbé Cochet found in a Gallo-Roman tomb in France a pewter bottle, which proved upon analysis to be composed of sixty parts of lead and forty parts of tin. The Franks had a metal called "potin," which was used in place of pewter, and was largely composed of lead.[2] Pewter, it seems, if these statements are accepted, was in use at a much earlier period in France than Hunt accords for its general use in England.

The London pewterers acquired great celebrity for their wares, which were sold to all parts of the world. The wardens of the pewterers had the inspection of pewter throughout the kingdom, and articles made of this alloy were required to bear the official stamp before being exposed for sale.

In early times the chalices and salvers used in the Protestant churches of England and Germany were commonly made of pewter, and it formed a large portion of the table furniture of the nobility and gentry of England so late as the time of Henry VIII. In the "household boke" of the Earl of Northumberland of that day is a charge for the

[1] Hunt, British Mining, p. 46.

[2] See Revue Archéologique, vol. xliii., 1882; also ib., third series, vol. i., 1883.

hire of pewter vessels, showing that it was too costly to be very common. Domestic articles of lead were sometimes used. In the inventory of the domestic utensils of Sir Thomas Ramsey, made in 1590, several vessels of lead, leaden weights, pewter candlesticks, and a quantity of unmanufactured lead are specified;[1] and in the inventory made for Sir William Fairfax, in 1594, appear, among others, the following: "Item: I seasterne of lead for barley; Item: VII leades for mylk," pewter "pottes," basins, ewers, etc. Among the articles forbidden to be imported into England in 1484 we find leaden spoons mentioned.

Sheet-pewter is said to have been the first metal used in plate engraving; and prints by two Florentine artists, who engraved upon this metal in 1460, are preserved in England. Albert Dürer is said to have first engraved upon pewter plates. It was used almost exclusively for engraving sheet-music for many years. Pewter was used in the middle ages in the execution of works of art. Francis Briot has been considered one of the most skilful artists of the sixteenth century, and the only examples of his work now known are in pewter. Cellini, in his treatise upon the goldsmith's art, recommends the goldsmiths to take proofs in lead of such of their works as were to be executed by casting to preserve them as models for other works.

The pewter work of the fourteenth and fifteenth centuries in France is said to have frequently been exquisite. The scarcity of gold and silver made it necessary for the goldsmiths to make plate of pewter to supply the demands of the middle classes, who followed the lead of the nobles in decorating their dressers; and some of these pewter vessels were of such rare designs and workmanship that they found places in the collections of royalty. The father of Francis I. of France, Charles, Count of Angoulême, owned in 1497 a large collection of pewter.[2]

[1] Archæologia, vol. xl.

[2] J. Labarte, Arts of the Middle Ages, p. 263.

Many interesting leaden objects are preserved in the museums of Europe, which are worthy of study and description by a competent archæologist. The field is comparatively unworked, and the subject is an important and an interesting one; but success can only be achieved by an ably supported enthusiast. It is to be hoped that the series entitled "Les Metaux dans l'Antiquité et au Moyen Age," published under the auspices of "La Nature," in which the sumptuous work by M. Germaine Bapst, "L'Etain," appears will be extended so as to cover a History of Lead by an author so felicitous and scholarly as M. Bapst.

CHAPTER IX.

WHITE LEAD IN ANCIENT TIMES.

IN primitive communities the ceaseless struggle to secure personal safety, and to procure the food necessary for daily sustenance, precludes any attempt to provide habitations beyond those necessary for shelter from the elements; but organization gives such communities power not only to resist attack, but to successfully assume the aggressive, and finally to command the services of their less thoroughly organized neighbors; they are thus relieved from the harassing care and toil so essential in primitive conditions of society to preserve existence. Under these improved circumstances life becomes less rude and a desire is conceived for a more commodious and convenient dwelling-place than the cave or rude hut or cabin which has hitherto served as shelter. The Egyptians, at the period of the erection of their oldest monuments, had passed through the evolution referred to, centuries before, and architecture and the arts of sculpture and of painting had long been cultivated. Heeren suggests that the study of these arts formed a part of the education of the priests, and that they were the directors in the erection of the stupendous structures which excite the wonder and admiration of the modern archæologist and scientist. The cultivation of the arts and sciences did not fail to create in the minds of the people a taste for decoration; we find, therefore, that the Egyptian monuments of as early a date as

the sixth dynasty (2500 B. C.) exhibit examples of sculptural and painted decoration of a very elaborate character. The walls of their tombs, their mummy cases, and mummy wrappers, were carefully prepared and decorated; their temples, and probably their dwellings, were painted and decorated inside and out; not only satisfying their artistic taste, but affording a gratifying and much needed relief from the glare of an equatorial sun blazing through a cloudless and transparent sky.

Wood was rare in Egypt, and was imported in great quantities; the more esteemed varieties formed a portion of the tribute exacted by the Pharaohs from conquered nations. Owing to the scarcity of timber, the walls of the dwellings of the Egyptians were usually built of unbaked bricks; the roofs were formed of beams of wood covered with clay, and both walls and ceilings were carefully stuccoed, and the former were laid off in panels, and painted in red, yellow, and other gay colors. As painted decoration preceded sculpture, the mouldings and other ornaments, afterwards cut in stone, were at first represented by painting in colors. The interior walls were often elaborately decorated with scenes of striking character, represented in colors and surrounded and set off by painted borders. The ceilings of the temples were frequently painted blue and sprinkled with stars, in imitation of the celestial vault. It is a curious fact, referred to by Heeren, that the early Egyptian artists used but five colors, — white, yellow, red, blue and green, — and did not combine them, evidently having no idea of the formation of shades or tints.[1]

The almost total destruction of the Assyrian cities renders it impossible to speak assuredly of the character of the decorations of their dwellings, but Smith describes several chambers in one of the palaces which he discovered when

[1] See Wilkinson, Ancient Egyptians, vol. ii. p. 277 *et seq.;* also Heeren, Historical Researches, vol. iii. p. 416.

digging in the mound of Nimroud, and says the walls were plastered and colored in horizontal bands of red, green, and yellow, and that even where the walls were panelled with stone slabs, the plaster and colors were continued over them. The outer wall, of which he found a portion, was faced with enamelled bricks, colored and representing battle scenes. He ascertained from inscriptions upon some of the bricks that the builder of the palace was Shalmaneser II., 860 B.C.[1] Layard describes chambers formed by walls of sun-dried bricks which were plastered and painted with figures and ornaments, but he was unsuccessful in discovering the subjects of the paintings, owing to his inability to remove the mass of débris without destroying the plaster. The subjects appeared to be processions of kings and warriors depicted in colors, red, blue, white and black; the figures were generally in black upon a blue ground. Layard found similar decorations in rooms in other parts of the mound.[2]

The Assyrians, therefore, as well as the Egyptians decorated their palaces, temples, and public buildings, in colors, and it is probable that they also thus decorated their more important dwellings.

The ancient Hindu temples strongly resembled the Egyptian in their general arrangement. They were guarded by colossal statues of gods and animals, and the interior walls were elaborately decorated with reliefs, which were gayly painted. The absence of the blending of colors to produce shades and tints is as noticeable here as in Egypt. "Neither people," remarks Heeren, "seem to have had the least idea of this art or of perspective."[3]

The decoration of the interior walls of ancient tombs was frequently very elaborate. The Egyptians considered

[1] George Smith, Assyrian Discoveries, etc. (New York, 1875), pp. 78, 79.
[2] A. H. Layard, Nineveh and its Remains, vol. ii. p. 17 *et seq.*
[3] Heeren, Historical Researches, vol. iii. p. 416.

this life as of little consequence, a mere tarrying-place, whereas the future life was indefinite; but before entering upon it one had to remain in the sepulchre for endless generations, and the continuance of existence depended upon the preservation of the body.[1] Hence the substantial character of the tombs, and the great care and cost expended in their construction and decoration. The walls of the Egyptian tombs were often entirely covered with scenes highly finished in colors. This custom was by no means peculiar to Egypt. In the caves of Ajunta and Baug, in India, wall-decorations of vast extent have been discovered, in which processions of elephants, and battle and hunting scenes are pictured in tasteful though florid colors. They are considered by archæologists to have been executed as early as the second century B.C.[2]

The Hebrews were acquainted with the art of painting. The paintings at Thebes were executed before the birth of Moses, and during their residence in Egypt the Hebrews must have become familiar with the customs of the Egyptians. Moses refers to paintings when he commands the Israelites, in passing into the land of Canaan, to drive out all the inhabitants from the land and to destroy all their pictures.[3] The prophet Ezekiel, looking through the hole in the wall, saw "every form of creeping things, and abominable beasts, and all the idols of the house of Israel, portrayed upon the wall round about."[4]

The Etruscans reached a high state of civilization. The graceful shapes of their vases, and the artistic and careful drawing of the figures with which they are decorated indicate a cultivation of the arts quite equal to that of the Romans of a much later day. They also decorated the

[1] Diodorus, vol. i. p. 56.

[2] Dr. Wilhelm Lubke, History of Art (New York, 1881, 2 vols.), vol. i. p. 109. See also American Journal of Archæology, vol. ii. p. 209.

[3] Numbers xxxiii. 52.

[4] Ezekiel viii. 10.

walls of their tombs and of their buildings with paintings. The style of their mural pictures is said to resemble that of the Egyptians, and shows but little advance over that nation in the use of colors; the figures in their paintings are generally in monochrome.

The ancient Greeks and Romans decorated their public buildings in a similar manner. Portions of many ancient Grecian temples still bear traces of the colors with which they were painted. The frieze of the temple of Theseus at Athens, the cornice and other parts of the Parthenon, still bear testimony to the prevalence of the desire for this style of decoration. The walls of the palace at Tiryns were elaborately decorated with rich geometric patterns and with figures of animals colored in white, black, blue, red, and yellow.[1]

The painting of sculpture was thought in ancient times to add to its beauty. The Egyptians very generally painted their sculptures. Layard mentions the prevalence of this practice with the Assyrians, and in Pliny's time it was universal. According to this author, when Praxiteles was asked with which of his works he was most pleased, he replied, "With those to which Nicias [a celebrated painter of the time] has set his hand." [2]

The Romans and the Greeks universally decorated the interiors of their dwellings. Pliny and Vitruvius give elaborate instructions respecting the method of preparing the walls, and grinding and mixing the colors, and add minute directions for spreading them. Vitruvius suggests and comments upon the proper character of the subject to be depicted.[3] The uncovering of Pompeii, after its remarkable sleep of more than seventeen centuries under the ashes of Vesuvius, has revealed to us much more clearly

[1] Schliemann, Tiryns, p. 297 *et seq.*

[2] Pliny, Natural History, book xxxv. chap. xl.

[3] Vitruvius, p. 210.

than any description could something of the domestic life of the Roman of the first century of our era. The homes of the wealthier classes, though small, were frequently decorated in a most luxurious and expensive manner. The pavements were laid in mosaic, and the walls were covered with bold designs painted in vivid and brilliant colors. Pliny and Vitruvius repeatedly refer to the extravagances of the time, and bewail the decadence of true art and good taste in the struggle of the wealthy to outvie each other in lavish expenditure. The walls of the Roman and Greek dwellings were originally painted in monochrome, and merely to preserve the stucco or plaster, and to prevent the absorption of moisture. This preservative coating was soon made more attractive by adding other colors, and finally the walls were divided into compartments or panels by the introduction of ornamental borders, and the panels were filled with elaborate designs representing figures and landscapes often boldly and skilfully drawn and painted in brilliant colors. Early Greek art seemed to be entirely subservient to the decoration of temples and public buildings, but the painters of Greece and Rome in the early days of the Empire found employment in the decoration of the homes of the wealthy.

The pigments used by the Egyptians and the Assyrians were ochres, clays, lime, and salts of copper, iron, arsenic, manganese, etc. Their blacks were composed of charcoal or other carbonaceous substances; their whites were of clay or lime; for blue and green they employed salts of copper and of iron; for yellow, ochres and arsenious sulphide; their reds were principally composed of earths colored with iron oxide; they probably employed cinnabar and perhaps lead oxides. Many writers refer to the remarkable brilliancy and freshness of the colors in the Egyptian tombs, and fancy that they possessed some method of preparing them unknown to modern manufact-

urers; but the persistence of the brilliancy of these colors is doubtless solely due to the remarkable dryness and equability of the Egyptian climate.

The Greeks and Romans used much the same pigments as the Egyptians, with the addition of cinnabar and lead oxides. White lead was used as a remedial agent in the preparation of plasters and ointments by the Egyptians, Greeks, and Romans. It is classed as a pigment by Pliny, who mentions it, among other colors, as being liable to injury upon its application to wet stucco. Other ancient writers refer to white lead as a pigment, and it was probably commonly used as such, but the researches of archæologists have thus far failed to discover any evidence of its use as a pigment in the examination of the paint found on the walls of buildings and tombs of ancient Egypt, Greece, and Rome. Lead oxides were undoubtedly used, as traces of this pigment have been found in several instances. Although Davy failed to find ceruse in his examination of the pigments discovered in the excavations at Pompeii, he believed that it was commonly used, and that the ancients employed salts of lead of different tints between Pliny's usta or minium, and imperfectly decomposed ceruse or pale massicot.[1] The failure to find traces of white lead in the analyses of paint used in the decoration of the monuments yet examined is negative evidence only, and cannot be accepted as proof that this pigment did not enter into other decorations of antiquity, the frescos and pictures in encaustic.

The ancient Romans attained to no inconsiderable skill in the preparation of pigments, and the manufacture and sale of colors was a well-established branch of industry and commerce. One of the shops discovered in the excavations at Pompeii had jars of pigments displayed in

[1] The Collected Works of Sir Humphry Davy, edited by John Davy, M.D., F.R.S. (London, 1839, 9 vols.), vol. vi. p. 139 *et seq.*

long rows ready for sale to the artist and painter. The methods of preparing colors, which were common in Italy at the time of the revival, in the twelfth century, were probably the same as those used by the ancient Grecian and Roman painters.

Pliny mentions the use of a native ceruse, found on the lands of Theodotus, at Smyrna, "which the ancients made use of in painting their ships." "At the present day," he continues, "all ceruse is prepared from lead and vinegar." [1] The native ceruse, suggests one of Pliny's commentators, was carbonate of lead ore, or cerussite. White lead, the cerussa of the Romans, is to-day one of the most important products of lead, consuming in its manufacture in the United States more than one third of all the metal produced. Nearly the entire production is used in the preparation of paint for preservative and decorative purposes. The well-known characteristics of white lead, its capacity for combination with linseed oil, — the vehicle universally conceded to be the best for most uses in painting, — its resistance to atmospheric influences, together with its great opacity, caused it to be recognized long ago by scientific and practical men as the most acceptable white pigment for general purposes, and as the proper base for colored paints.

The method employed in England and in the United States in the production of white lead, except for an insignificant quantity, is that known as the Dutch process, and is based upon the following principles. When metallic lead is exposed to the action of atmospheric air and moisture, it becomes covered with a white substance composed of carbonate and hydrated protoxide of lead, which is the white lead of commerce. This action is facilitated by subjecting the metal to a moderate heat, slight pressure, and surrounding it with the vapors of acetic acid.

[1] Pliny, Natural History, book xxxv. chap. xix.

White lead is produced by the Dutch process by artificially creating these conditions, and submitting metallic lead to the corroding effects of a warm atmosphere loaded with the vapors of carbon dioxide, commonly known as carbonic acid gas, of acetic acid, and of steam.

The theory of the chemical reactions perhaps most generally accepted is as follows: Lead has a great affinity for oxygen, and is readily attacked, resulting in the formation of a minute film of lead oxide. This oxide is in turn invaded by the vapors of acetic acid, resulting in the formation of a double acetate of lead, the normal acetate, and a basic acetate; carbon dioxide now combines with this basic salt, forming commercial white lead and normal lead acetate, which latter unites with a portion of the freshly formed oxide, producing basic acetate, which in turn undergoes the changes just described. This process is repeated again and again, a minute layer of white lead being formed each time, until all the metallic lead has been converted, or so long as all the conditions requisite are present.

The above theory, as before stated, is generally adopted, but it is not fully endorsed in all its details by some investigators of recognized authority. Hochstetter considered that he had practically proven that the normal acetate is decomposed by carbon dioxide into commercial white lead, and that the acetic acid is set free to again attack the lead oxide and form the acetate, as in the first case. However authorities may differ regarding the details of these reactions, nearly all agree that at first a salt is formed, which is afterwards decomposed, but which gives by that reaction a substance which is capable of producing the first, and that this process is continually repeated so long as all the conditions requisite are present. Mulder defines commercial white lead as an intimate mixture of the carbonate with the hydrated protoxide of

lead, the usual product being two parts of the carbonate to one of the hydrated protoxide, though occasionally the combination consists of three or in extreme cases more parts of the carbonate to one of the hydrated protoxide. Gmelin describes white lead as a white, earthy, dense and heavy mass, which possesses greater coating power than any other white pigment by whichever process prepared. Under the miscroscope, diffused through water, it appears to consist of non-crystalline, transparent, round, and oval globules of 0.00001, and rarely 0.00003 to 0.00004 of an inch in diameter. White lead prepared by new methods, he says, consists of globules somewhat larger and more transparent.[1]

White lead was known to the ancients under its Greek name *psimithium*, or its Roman name *cerussa*, the latter word connected perhaps with the latin word *cere*, wax, probably because the Romans used melted wax in preparing the vehicle for spreading it, or from its use in painting in encaustic. The earliest account of the method employed in its preparation is contained in Theophrastus's "History of Stones," a work written about three hundred years before Christ. This author describes the manufacture of white lead as follows: "Lead is placed in earthen vessels over sharp vinegar, and after it has acquired some thickness of a sort of rust, which it commonly does in about ten days, they open the vessels and scrape it off, as it were, in a sort of foulness; they then place the lead over the vinegar again, repeating over and over again the same method of scraping it till it has wholly dissolved. What has been scraped off they then beat to powder and boil for a long time, and what at last subsides to the bottom of the vessel is ceruse."[2] Vitruvius, a Roman architect of the first century, B. C., says: "It will be

[1] Gmelin, Handbook of Chemistry, vol. v. p. 125.

[2] Theophrastus, History of Stones, p. 223.

proper to explain in what manner white lead is made. The Rhodians place in the bottom of large vessels a layer of vine twigs, over which they pour vinegar, and on the twigs they lay masses of lead. The vessels are covered to prevent evaporation, and when, after a certain time, they are opened the masses are found changed into white lead."[1] Pliny, writing a hundred years later, says, "Psimithium, which is also known as cerussa, is another production of the lead works, and the most esteemed comes from Rhodes." This is quite in accordance with the reputation of the Rhodians, who were celebrated at that time throughout the civilized world for the extent and the excellence of their manufactures. Pliny describes the process of manufacture in his time as follows: "It is made from very fine shavings of lead placed over a vessel filled with the strongest vinegar, by which means the shavings become dissolved; that which falls into the vinegar is first dried, and then pounded and sifted, after which it is again mixed with vinegar and is then divided into tablets and dried in the sun during summer. . . . It is also made in another way. The lead is thrown into jars filled with vinegar, which are kept closed for ten days; the sort of mould which forms upon the surface is then scraped off, and the lead is again put into the vinegar until the whole of the metal is consumed."[2]

Dioscorides, who wrote, in the first or second century, a work on Materia Medica and Botany, which in some particulars was accepted as authority for fifteen hundred years, also describes the process of converting metallic lead into white lead. He says: "Ceruse is made in the following manner: having poured vinegar, as sharp as possible, into a broad-mouthed pitcher, or an earthen jar, fasten firmly a mass of lead near the top of the jar upon a mat

[1] Vitruvius, p. 186.

[2] Pliny, Natural History, book xxxiv. chap. liv.

of reeds, previously stretched beneath, and throw over the jar a cover, that the vinegar may not evaporate until the lead, dissolved and dripping down like rain, has disappeared; then having strained off the clear water, which remains upon the surface, pour into a vessel that which is viscid; this must then be dried in the sun, presently pulverized in a handmill, or in some other manner, and sifted; afterwards what remains hard or solid must be reduced to fine particles and likewise sifted; the same process must be repeated in turn three or four times. That is the best which first passes through the sieve, and this must also be employed for the relief of the eyes; that which is next sifted out holds the second place, and in succession the others in their order. Others," he continues, "having suspended a stick of wood about the middle of the jar, place the mat of twigs before mentioned upon it, in such a manner that it may not touch the vinegar, and throw in the lead, putting on a cover and sealing it tightly. After ten days, removing the cover they look in, and when the material has been dissolved they complete the other operation as we have described." Dioscorides also states that the work can be done in the winter as well as in summer, "if you place the jar over braziers, cauldrons, or furnaces; for heat applied to it shows the same effect as the sun." [1]

The descriptions given by the writers just quoted of the methods employed in the manufacture of white lead by the ancients are not acceptable to modern science. They fail to provide for the presence during the operation of carbon dioxide, and Dioscorides alone mentions the necessity for a gentle heat. Their methods literally followed would produce lead acetate, and not white lead; and some modern writers have denied that the ancients really knew the

[1] Pedanius Dioscorides, De Materia Medica (Curtius Sprengel, Leipsic, 1829, 2 vols.), vol. i. p. 769.

substance which we term white lead. Lead acetate is unsuitable for use as a pigment. It is freely soluble in water, and possesses no opacity or covering properties when mixed with a suitable vehicle for use in painting. Pliny and other early writers refer to white lead as a pigment, and there is every reason to believe that it was used for such purposes, while lead acetate was then, as now, a remedy in therapeutics, and was probably confounded with white lead, and both substances were commonly known as cerussa.

While the ancients were acquainted with and successfully conducted many chemical and metallurgical processes their knowledge was purely empirical, and they did not comprehend the rationale of the reactions which occurred directly under their eyes. Except for physical characteristics, appearance, taste, odor, weight, etc., they were unable to detect the difference between white lead and lead acetate. Their ignorance of the difference in the composition of these substances would unquestionably lead, in some cases, to their use indifferently for the same purposes.

The ancient manufacturers seem to have clearly understood one of the requisites in modern practice in the preparation of white lead, — the necessity for supporting the lead above the acid so that it should not be wetted by it. Theophrastus, Vitruvius, Pliny, and Dioscorides, each insist upon it; but there are statements in their descriptions which imply that lead acetate alone was produced. Dioscorides describes the process of manufacture in such a manner as to lead us to infer that the ancients found the lead dissolved in the acid. He says "it dripped down like rain," and after straining off the clear water that which was viscid was dried in the sun. He also says that the first which passed through the sieve was used for the relief of the eyes.

It is difficult to believe that modern commercial white lead was produced by the methods described by these ancient authors. The description of the product and of the manipulations after the completion of the chemical reactions all point to lead acetate as the result of the operation. The after-manipulation is, however, not altogether inconsistent with the production of both substances at the same time and in the same apparatus. Dioscorides' account may be thought to imply this, and Boerhaave, fifteen hundred years later, describes an apparatus by which both lead acetate and white lead may be prepared by one and the same operation. But Dioscorides alone refers to the necessity for heat, and none of the old writers give us any clue to the source from which they obtained their carbon dioxide. According to Hoffmann, Galen, in the second century, says that white lead is made by dissolving litharge in vinegar, burying the vase containing these substances *in dung*, for forty days.[1] We have here a source of heat mentioned, and it is extremely probable that this natural source of heat had long been known and used for similar purposes. The notice of the use of dung in aid of chemical reaction at this early day is important, but as the writers generally direct that the vase shall be closely covered, it is not probable that this substance furnished any other adjunct to the reaction than the heat evolved in its decomposition.

If our examination of the methods as described by these ancient authors closed here, we should be forced to confess that the writers who contend that the ancients were unacquainted with modern commercial white lead are probably correct, as no reference has been made by any ancient writer to the means of securing the presence of carbon dioxide. There is no question respecting the necessity for providing for the presence of this element in some other way than that suggested by certain writers, namely, its possible produc-

[1] Hoffmann, Das Blei, etc., p. 42.

tion in the decomposition of acetic acid. It has been shown by Ludowig and others that if lead is exposed to the vapors of acetic acid in closed vessels, the formation of a carbonate would not occur. Hochstetter exposed lead to the vapors of acetic acid in air which was free from carbon dioxide, and nothing but lead acetate was formed.[1] Merimée conducted a crucial experiment to determine this question. He placed under a bell-glass a capsule filled with pure vinegar, and adjusted upon it some plates of lead, separated from each other in such a manner as to allow a free passage for the vapors of the vinegar on all sides; he then luted the bell-glass carefully upon the plate which supported it. He next prepared a similar apparatus, but he put into the vinegar some pieces of marble, which produced, by their decomposition, carbon dioxide. The two bell-glasses were then exposed to the same temperature, 35°–40° centigrade, during a month. At the end of this period the plates of lead in the glass which contained the pure vinegar were covered with a crystalline and transparent layer of lead acetate, which had not a trace of carbon dioxide in its composition; while the plates in the other glass were covered with a layer, more or less thick, of the white lead of commerce, which proved, after drying, to be equal in quality to the finest Krems white.[2]

The ancient authors whose descriptions of the methods employed in their time in the manufacture of white lead we have quoted, doubtless had no practical knowledge of the process, and trusted entirely to other and earlier authors for their information upon this subject; consequently the omission to refer to the presence of one constituent, though it be as in this case an all important factor, might easily escape the notice of those unacquainted with the

[1] See Gmelin, Handbook of Chemistry.

[2] J. F. L. Merimée, de la Peinture à l'Huile (Paris, 1830), p. 226.

rationale of the process and the absolute necessity for the presence of such an element. This theory would naturally and easily explain any deficiency in their descriptions; but this deficiency may be made to disappear, if we examine into the probable condition of the acetic acid used by the old manufacturer.

Common vinegar is dilute acetic acid combined with vegetable impurities. It is probably the oldest acid known. Dussauce suggests that its discovery must have immediately followed the discovery of wine, as in the warm countries, where the first experiments were made on the juice of the grape, fermentation must have set in very quickly, and the wine must have changed into an acid compound.[1] Although vinegar was generally known at a very remote period, the theory of its production was not understood until a comparatively late day. The method of concentrating and purifying it was unknown previously to the sixteenth century.

The methods employed by the ancients in the manufacture of vinegar were probably much the same as those in use at the present day in the wine-growing districts of Europe, where every farmer and vineyard proprietor manufactures his own vinegar. These domestic manufacturers provide a number of barrels of small capacity, which they place in their cellars; into these barrels they throw the residuum of the grapes after pressing, the lees of their wine, and any wine which has become unfit for drinking purposes. The temperature of their cellars is nearly uniform, and time only is needed for the conversion of the material into an acid compound. No process of manufacture is employed, but the acetic fermentation, after it has begun, continues, so long as the necessary conditions prevail. As the vinegar is required for household purposes, it is drawn from the casks, and as materials

[1] H. Dussauce, The Manufacture of Vinegar (Philadelphia, 1871), p. 19.

accumulate they are added.[1] The residuum of the grapes, which rises to the top of fermenting tubs, acidifies very rapidly, and is used in wine-growing countries in the manufacture of vinegar. In these natural processes the alcohol produced by the oxidation of the *must*, or unfermented juice of the grape, takes up another portion of oxygen during the acetic fermentation, and becomes vinegar, or dilute acetic acid, while the vinous fermentation continues in the lees or residuum of the grape, forming alcohol, and disengaging carbon dioxide in considerable quantities. Pliny tells us that the must of wine is subject to a spontaneous fermentation a second time, and that when this happened it lost all its flavor and received the name of "vappa." This substance was vinegar, but the word was also used to designate vinegar which, by exposure to the air, had lost its flavor. This author also states that a common method of testing wine was by placing in it a plate of lead; should the wine prove to be turning sour, a reaction would result, the acetic acid generated in the second, or acetous fermentation of the wine, would attack the lead, forming upon it a film of lead acetate. Pliny also states that "it is a peculiarity of wine among the liquids to become mouldy or else to turn to vinegar." [2]

If we therefore assume that the ancients made their vinegar by these simple processes, the difficulties suggested above disappear at once; as the source of the carbon dioxide is thoroughly accounted for, — the unpurified vinegar containing notable amounts of substances which, in fermenting or decomposing, produce carbon dioxide.

Theophrastus tells us that verdigris was made in a manner something resembling the method of preparing white lead. Copper was placed in vessels over the lees of wine, and the "rust" which it acquired by this treat-

[1] See Dussauce, The Manufacture of Vinegar, p. 205.

[2] Pliny, Natural History, book xiv. chap. xxv., xxvi.

ment was taken off for use.[1] Beckmann, commenting upon this passage, says the Greek word used by Theophrastus had more than one meaning. It sometimes signified wine lees, and sometimes squeezed grapes, or the residuum after expressing the juice; he concludes that the ancients used for this purpose "the sourest vinegar, or the sour remains left when they made wine, such as grapes which had become sour, or the stalks and skins after the juice had been expressed from them."[2] If the ancients used wine lees, or the refuse of the grapes after pressing, with the vinegar in making white lead, the source of the carbon dioxide is satisfactorily accounted for, and true white lead would be produced.

This suggestion receives support in modern practice. At Klagenfurth, in Carinthia, white lead is made in closed chambers, — the acetic acid and the carbon dioxide being simultaneously produced by the fermentation of the extract of dried grapes or raisins, or of the residuum of grapes after pressing. Water-tight boxes are prepared, into which the raisins or the residuum is placed; to this is added a quantity of vinegar. When subjected to heat, the vinous fermentation begins in the sweetish liquor, producing alcohol and carbon dioxide, and the acetic fermentation also occurs in the alcohol, producing acetic acid, while at the same time the vinegar is volatilized; thus the chamber, in which the apparatus is erected, is filled with the warm vapors of acetic acid, carbon dioxide, and of steam, and the conditions requisite for the conversion of metallic lead into white lead are present.[3]

If we accept this theory we must admit that the ancients produced the substance we now know as white lead,

[1] Theophrastus, History of Stones, p. 225.

[2] Beckmann, History of Inventions, etc., vol. i. p. 172.

[3] J. G. Gentele, Lehrbuch der Farbenfabrikation (Braunschweig, 1880), p. 135.

and that their process differed but little from that adopted in some modern factories. Dung was probably used as a source of continued and gentle heat, though not at that time as a source of carbon dioxide. While it may be safe to say that the ancients produced true white lead, their preparations would scarcely sustain modern tests for excellence. It is probable that their white lead contained an excess of acetic acid, or was largely contaminated with lead acetate, and, as has been remarked above, these two substances, white lead and lead acetate, were used indifferently for the same purpose.

White lead was probably made in notable quantities at the beginning of our era. Rhodes seems to have been the most important seat of its preparation. Vitruvius describes the Rhodian method, and Pliny says that made at Rhodes was the best; while, according to Dioscorides, white lead was made in great perfection at Rhodes, at Corinth, and at Lacedemonia, and of an inferior quality at Puteoli.[1]

Cosmetics were universally used by women in ancient times; the old and the young, the married and single resorted to this means of improving their appearance. In its natural state white lead served as a powder, and colored with the juices of plants — generally the *Anchusa Tinctoria* — as rouge for heightening the color of the cheek. White lead colored in this manner has been frequently found in the sepulchres of Greek women. A little box of this cosmetic from the tomb of a Roman lady is preserved in the museum at Naples. The writers of that age make frequent references to the use of ceruse as a cosmetic by the women. Hoffmann quotes the following quaint story from Xenophon: —

"Ischomachus had a beautiful young wife, who followed the prevailing fashion and rouged and powdered her lovely

[1] Dioscorides, De Materia Medica, vol. i. p. 769.

face, and moreover wore high-heeled shoes to add height to her figure. 'Tell me, my dear wife,' said Ischomachus to her one day, 'in which case would you consider me the more worthy of your affection and esteem, if I truly informed you of my estate, or if I pretended to possess more than I really owned, and concealed some things from you, — if I gave you false silver, a wooden chain plated with gold, and purple raiment which would not retain its hue.' 'Oh! don't speak so,' interrupted his wife, 'you could not do such a thing. If you were like that I could not love you.' 'Then,' said Ischomachus, 'dear wife, have we not a partnership in our bodies as well as in our possessions?' 'Yes,' she replied, 'it is so considered.' 'Then,' said Ischomachus, 'would I treat you with the most loving consideration if I smeared my body with minium, and painted under my eyes in order to deceive you; or if I so cared for my body that it should be healthy and strong, and thereby be in truth and by nature painted. Would you prefer, when you pressed your lips to my cheek, to touch my own natural and healthy skin, or a plaster of ceruse and minium?' 'Ah!' she cried, 'it would be much more pleasant to touch your skin, and to see you as you really are, and not with powder on your cheeks and paint under your eyes.' 'Believe me,' said Ischomachus, 'I like not ceruse nor minium on your dear face.'" He then explained to her that such arts might possibly deceive a stranger, but could not her husband, as the bath and her tears would soon remove the cosmetic coating. The young wife was quickly persuaded that as every creature in his own natural condition best pleases himself, so man considers the unadorned beauty of woman the most adorned.[1]

Pliny refers to the use of ceruse by the women to whiten the complexion, and says it is, like the scum of silver, a

[1] Hoffmann, Das Blei, p. 46.

deadly poison. A supposed discoloration of white lead by the action of sunlight is perhaps referred to by the Roman poet Martial when he says: —

> "The chalked Fabulla fears the pouring rain,
> Cerused Sabella dreads the blazing sun."[1]

The use of white lead as a cosmetic, notwithstanding its well-known poisonous qualities, persisted until comparatively recent times, and our modern poets have referred to it: —

> "Fair virgins blushed upon him, wedded dames
> Bloomed also in less transitory hues;
> For both commodities dwell by the Thames,
> The painting and the painted, — youth, ceruse."[2]

[1] Martial, Epigrammatica, lib. iii. e. xli.
[2] Byron, Don Juan, canto xi. s. xlviii.

CHAPTER X.

WHITE LEAD, EIGHTH TO TWELFTH CENTURY.

MANY modern writers state that upon the dismemberment of the Roman Empire the manufacture of white lead was monopolized by the Arabs, who introduced the industry into Spain after they had conquered that country. But the methods employed by the Romans in the preparation of white lead were known in Spain a century before the invasion by the Arabs. Isidore, Bishop of Seville, was a man of great learning, piety, and influence, and a voluminous writer upon many subjects. He lived late in the sixth and early in the seventh centuries (he died in 636), and his most elaborate production was an encyclopædic work, which is really a compendium of the scientific knowledge of his time. In this work the method of preparing white lead is described, but the author closely follows Pliny and other early writers, and indicates no improvement in the methods proposed by them. He says: "White lead is made by putting vinegar into a vessel, and then placing therein twigs, upon which thin laminae of lead are fixed. The vessel is then closely covered, and after thirty days, if you open it you will find the white lead. It is then washed, dried, and pulverized, mixed again with vinegar, divided into tablets, and dried in the sun." This author also states that white lead is made from stannum, meaning perhaps Roman stan-

num, or argentiferous lead.[1] Geber, in the eighth century, mentions white lead and says that it is prepared by suspending plates of lead over vinegar; after a time a white substance forms upon the lead, which must be scraped off and dried in the sun, or by a gentle heat.[2]

The period known as the "dark ages" furnishes but little material for the subject under discussion. The decay and fall of the Roman Empire was followed by the settlement, in her European provinces, of barbarous nations, resulting in many cases in the gradual change of language. Literary pursuits were abandoned, and Hallam tells us that after a generation or two, if one desired to study he found himself obliged to learn another language, as the literature which had escaped the vicissitudes of war was locked up in manuscripts written in Latin or Greek. For several centuries it was rare to find a layman who could read, and the parish priest was frequently unable to sign his name, or to understand and to translate into his own language the prayers he daily repeated.

From the third to the tenth century but little progress was made in the arts and sciences in Europe. Scholars and students were persecuted, and finally, to avoid being pressed into military service, they fled to Bagdad where the Arabs had established schools of philosophy. The works of Aristotle, Galen, and of other Greek and Roman philosophers, brought to Bagdad by these scientific refugees, were translated into Syriac, and were afterwards taken by the Arabians to their schools at Granada and Cordova, where their philosophers cultivated the arts and sciences and made many important discoveries in astronomy, botany, and in other branches of science.

The decline in learning in Europe was most conspicuous in the sixth century. In the seventh, Bede of England and

[1] Divi Isidori, Hispal. Episcopi, etc., Madrid, 1599.

[2] Gebri, Regis Arabum Chymia (Gedani, 1682), p. 209.

Isidore of Seville, says Hallam, were the only writers worthy of note. The tenth century has been considered the most barbarous among Christian nations.[1]

The preservation of existing manuscripts of this early period is chiefly due to the religious fraternities, whose members, under the quiet routine and stern discipline of their establishments, found leisure for literary pursuits and for the cultivation of the arts and technical processes. Such manuscripts as they preserved were laboriously copied and exchanged with other religious houses. Their rarity now may be accounted for by the fact that the conquest of Alexandria by the Saracens cut off from Europe the supplies of papyrus upon which the earlier manuscripts were written, and the skins necessary to prepare the parchment which was used as a substitute became very scarce and dear. To such straits were the copyists driven that very valuable old manuscripts were frequently erased to provide material for transcribing works now of little or no value.[2]

The religious orders, already rich and powerful, received large accessions to their membership, as early as the eighth century, from those who desired to escape from the tyranny of the nobles and from the hardships of the military service. The monks organized schools and corporations of workmen and artificers. They monopolized many trades and undertook the foundation of great establishments. The arts and technical processes, destroyed in the secular world, were preserved and flourished in the seclusion and quiet of their monasteries. For many centuries the monks were the only scholars, artists, physicians, and manufacturers

[1] See Hallam, Middle Ages, vol. iii. pp. 260 *et seq.*; also Paul Lacroix, Science et Lettres au Moyen Age (Paris, 1877), p. 117 *et seq.* A superstition very generally prevailed during the dark ages that the world would come to an end in the year 1000. It has been suggested that the belief in the certainty of this catastrophe was perhaps the occasion of the suspension of all progress. After the passage of this date, without fatal consequences, a general reaction followed.

[2] Examples of this mutilation of MSS. are preserved in the British Museum.

of any but the rudest and coarsest wares; every monastery had its dispensary and its laboratory, its collection of minerals, and its botanical garden. The friars were the architects, builders, and decorators of their cathedrals and monastic establishments. They built roads and bridges.[1] In some countries the monks added trading and commerce to their other pursuits. In the seventh and eighth centuries they were granted extraordinary privileges in France, their goods were free of all tolls and duties, and their control of trade added largely to their wealth. Their monopoly of commerce finally became so oppressive that Charlemagne, in the ninth century, restricted their operations by prohibiting personal traffic by monks.[2]

The artistic skill, refined taste, and wonderful patience of the monks is well attested by the elaborate character of the decorations of the religious manuscripts of the middle ages. Before the invention of printing, all books were copied and decorated by hand. This work was almost exclusively performed by the friars, and in every monastic establishment one room was set aside for this purpose and called *the scriptorium*. The work was usually divided into two branches: the illuminators or decorators were called *miniatori*, or miniature painters;[3] the writing of the manuscripts was the work of other monks, who were termed

[1] The Friars of Pont Saint Esprit built a bridge of stone 2,800 feet long, carrying it across the stream upon twenty-two massive arches.

[2] See Leger, Les Travaux Publics, etc., pp. 738, 739; Pigeonneau, Histoire Du Commerce, etc., p. 108 *et seq.*

The Cistercian monks in England, so late as 1344, were exempt from all public taxes, and those who settled in Lincolnshire became merchants. MACPHERSON: Annals of Commerce, vol. i. p. 532.

[3] The word "miniatori," or miniature, is derived from "minium," the ancient name for red lead. The first illuminating consisted simply of red lines at the top and bottom, and occasionally at the sides of the page. The initial and capital letters were also frequently written in minium. In early printing the initial and capital letters were illuminated in red by hand. The word "rubrics" applied to the directions for service in the modern prayer-book of the church, is derived from the Latin word "rubrica," red.

miniatori caligrafi. Sometimes the entire work was performed by one and the same person, in which case he was termed a "writer," and the term "writing" was applied to painting, and was not confined to miniature painting, but also to painting upon glass.[1] Examples of the exquisite work of the artist monks are familiar treasures in public and private libraries. Many are quite extraordinary in the character and the elaborateness of their decoration.[2]

To some of these old manuscripts, these links in the chain of art connecting our own times with the glories of Greece and Rome, — links which would have been lost, and the chain irreparably broken, but for their fortunate preservation by the monks of the middle ages, — to these manuscripts we must refer to connect the methods employed in the preparation of white lead in modern times, with the practice of the ancient Grecian and Roman manufacturers.

In his ponderous work on the Italian antiquities of the middle ages, Muratori publishes a Byzantine manuscript which is ascribed by competent authority to the eighth century. Among a miscellaneous collection of recipes we find the following: "Concerning the making of Psimitthin (white lead). Take strong vinegar and place it in a pot so that it can evaporate. Then take long thin plates of lead and suspend them above the vinegar so that the fumes may pass over them. The sediment quickly

[1] See Mrs. Merrifield, Original Treatises on Arts of Painting (London, 1849), vol. xix. p. 3; also C. L. Eastlake, History of Painting (London, 1847), p. 11 *et seq.* The modern sign-painter is called by the craft a "sign-writer."

[2] The choral-books of the Convent of San Marco at Florence occupied several monks five years, while the thirty books belonging to the Cathedral of Ferrara required no less than fifty-eight years to complete. The monks who could read were urged, "if they desired to please God," to copy MSS., and those who were illiterate were desired to learn how to bind them. Great care was used to prevent and to correct errors in copying the MSS. Lacroix quotes from the collection of Baluze (in 789) "On aura de bons textes catholiques dans tous les monastères afin de ne point faire de demandes à Dieu en mauvais langage." See Lacroix, Les Arts au Moyen Age (Paris, 1874), p. 438 *et seq.;* also Mrs. Merrifield, Original Treatises, etc., p. 29.

subsides, and the clear acid is left in the jar. Wash in water three times and dry in the sun; wash again until all roughness is removed, and again dry in the sun."[1] This formula it will be observed is similar to the methods described by Theophrastus, Vitruvius, and other earlier writers and it was probably copied from an earlier manuscript or directly from the works of Theophrastus or Vitruvius.

In 1774, Lessing, at that time librarian to the Duke of Brunswick, discovered in the library at Wolfenbüttel, bound up with one by Vitruvius, a manuscript bearing the title, "Diversarum Artium Schedula" by Theophilus, Presbyter. This work was referred to by a writer as early as 1555, at which time but two copies were known to exist, — one in the possession of George Agricola, and the other in the library of the convent of Alten Zelle. Lessing thought that the one then in the library under his charge was the copy formerly owned by Agricola; the other had been finally placed in the library at Leipsic.[2] Raspe, an English scholar, discovered a copy of this manuscript in the library of Trinity College, Cambridge, and one in the Cambridge University Library; another copy is in the Nani Library at Venice; a sixth is bound with other manuscripts in a collection by Jean Le Begue, and is in the Royal Library at Paris; and finally the seventh, and by far the most complete, was found, in 1844, among the Harleian manuscripts in the British Museum. Some of these copies are incomplete; but they abound in information relating to the manufacture of glass, to the working of metals, and to painting in fresco, in encaustic, and to the use of oil in painting on wood, canvas, and on vellum. The directions for the use of oil in painting contained in this manuscript were the occasion of much discussion and remark when

[1] Muratori, Antiquitates Italicae Medii Aevi (Mediolani, 1738), vol. ii. p. 370.

[2] Vom Alter der Oelmalerei, Lessings Sämmtliche Schriften, Karl Lachmann (Berlin, 1839, 9 Band), s. 443.

public attention was directed to it by Lessing, in a pamphlet noticing this portion of the treatise; as previous to that time the invention of the art of painting in oil had been attributed to Van Eyck, a Flemish painter who lived in the fifteenth century. There is nothing in the manuscript by which either the time in which it was written or the country of the author can be definitely fixed. He calls himself "Theophilus, a humble monk and priest;" in the copies at Venice and in the British Museum he is also called "Rugerus," which is supposed by some to have been his true name, "Theophilus" being a common name among the monks, assumed by them upon entering holy orders. Lessing thought that undoubted indications existed that Theophilus was German, and identified him with a monk of the Convent of Saint Galle, named Tutilo, who was known to be a great painter and artist, and who lived in the ninth century. Lessing argued that the work is evidently of as early a date as the ninth century, and supported his argument by pointing out that "Tutilo" is German for the Greek name "Theophilus." [1] Later authorities generally agree with Lessing that Theophilus was probably a German, as many terms used by him are German, and all the copies of the manuscripts yet discovered which are at all complete have been shown to have come from Germany.[2] Tambroni, however, insists that Theophilus was certainly an Italian.[3]

While an approach to harmony exists as to the nationality and name of the author of this remarkable manuscript, there is a great diversity of opinion as to the time in which he wrote. Lessing thought the manuscript at Wolfenbüttel was copied in the tenth or the eleventh century; that at

[1] Lessing, Vom Alter der Oelmalerei, p. 450.

[2] Robert Hendrie, Translation of Theophilus, p. 20.

[3] Sig. Tambroni, in preface to A Treatise on Painting by Cennino Cennini, translated by Mrs. Merrifield (London, 1845), p. 51.

Leipsic is considered to be of the fourteenth century; that discovered by Raspe at Cambridge University library, and the copy he afterwards found in Trinity College library, "are written," he says, "on vellum, in a character such as was used in the thirteenth century."[1] The copy at Paris, in the collection of manuscripts made by Le Begue, is of the fifteenth century, while that at Venice is said to be as late as the seventeenth century.

Raspe contends that Theophilus must have lived in or about the tenth century. Lessing, as we have seen, fixes the date as early as the tenth or eleventh; Hendrie places the work as of the early part of the eleventh century,[2] while Guichard, in his introduction to the translation by L'Escalopier, says that a work which treats so elaborately of painting, of illuminating, engraving, founding of metals, building of organs, etc., has a place only in the time of the Renaissance, "such, in modern history, is the character of the twelfth and thirteenth centuries, which gave to science Roger Bacon, Raymond Lulle, Dante, Cimabue, Giotto, Saint Bernard, Louis IX., the Crusades, etc."[3]

In Trinity College library, Cambridge, Raspe found, in 1774, bound with a copy of Theophilus, a manuscript entitled "De Coloribus et Artibus Romanorum, by Eraclius;" Raspe pronounced this copy to be in the handwriting of the thirteenth century.[4] But one other copy of this manuscript is known to exist, and that is in the collection made by Le Begue, and preserved in the library at Paris. The same uncertainty exists as to the time and nationality of Eraclius that is observed respecting Theophilus. Raspe says: "Both seem to have lived in the darkest ages of

[1] R. E. Raspe, A Critical Essay on Oil Painting, etc. (London, 1781), pp. 39, 42.

[2] Hendrie, Translation of Theophilus, p. 15.

[3] Cte. Charles de L'Escalopier, Théophile, Prêtre et Moine, Essai sur Divers Arts (Paris, 1843), introduction par J. Marie Guichard, p. 49.

[4] Raspe, A Critical Essay on Oil Painting, p. 42.

monkish ignorance."[1] The name Heraclius or Eraclius is Greek, but the fine arts were cultivated at Rome during the period of her greatness by Greek artists, or by artists of the Greek school, and Greek names were common in Italy after the dismemberment of the Roman Empire. Eraclius does not appear to have been a monk, but addresses his work to a friar or brother. Raspe denounces him as "an ignorant quack," because he speaks of his secrets "with the boasting consequence of an empyric."[2] He further says: "We are not much mistaken in supposing he lived and wrote soon after Isidore of Seville."[3] Hendrie thinks he did not write later than the latter part of the tenth century.[4] It is probable that some portions of the manuscript of Eraclius were written before that of Theophilus, but other portions are undoubtedly later; and Mrs. Merrifield is perhaps correct in the suggestion that a portion of the manuscript is simply a miscellaneous collection of recipes and works on art, of various origins, made by some compiler at a period greatly subsequent to the original work of Eraclius.[5]

Another ancient manuscript relating to the arts, entitled "Mappae Clavicula," was noticed some years ago, in "Archæologia," by Sir Thomas Phillipps, then the owner of the only copy known to exist. Phillipps published a transcript of this manuscript, which is supposed to have been written in the twelfth century. The author is entirely unknown, but Phillipps suggests that he may have been an Englishman, who lived in the twelfth century, and that the methods described are those used by the Anglo Saxons. It is also pointed out that the places referred to are in Italy and southern Europe, and that a similarity exists

[1] Raspe, A Critical Essay on Oil Painting, p. 36.
[2] Ibid., p. 46.
[3] Ibid., p. 47.
[4] Hendrie, Translation of Theophilus, p. 14.
[5] Mrs. Merrifield, Original Treatises, etc., vol. i. p. 180.

between the processes described in this and in other manuscripts of equally uncertain origin and date. It is suggested that it is not easy to determine whether this is older than parts of Eraclius or not; [1] by some it is considered older, as it does not mention painting in oil,[2] but authorities seem to agree that portions of Eraclius are older.

There is preserved in the Bibliothèque Royale, at Paris, a manuscript of Jehan Le Begue, a Licentiate in the Law, and Notary of the Masters of the Mint at Paris. This manuscript, compiled in 1431, is referred to by Lessing as containing a copy of the manuscript of Theophilus.[3] It contains a portion only of that interesting work, but it includes one of the two copies of the manuscript of Eraclius which are known to exist. Le Begue says he compiled the manuscript from a collection of works on painting made by Jehan Alcherius, or Alcerius.

Little is known of Alcherius, except that he devoted the better part of his life to the formation of this collection of recipes. The first notice of him is in 1382, when he was living in Milan. He visited Paris during this year, and for thirty years afterwards he appears to have travelled extensively in France and Italy, residing in Paris, Milan, Padua, Bologna, Venice, and other Italian cities, associating with painters and artist-monks, collecting and copying recipes for painting, gilding, the preparation of pigments, etc. At the date of the last notice of him, late in 1411, he was in Paris, recopying and correcting the manuscripts he had collected. Twenty years after, Le Begue copied the manuscript of Alcherius into one volume, to which he added a copy of a portion of the manuscript of Theophilus, a manuscript of Petrus de Sancto Audemaro,

[1] Mrs. Merrifield, Original Treatises, etc., vol. i. p. 167.
[2] C. L. Eastlake, History of Painting, vol. i. p. 32.
[3] Lessing, Vom Alter der Oelmalerei, p. 448.

and three books by Eraclius, entitled "De Coloribus et Artibus Romanorum."[1]

The weight of authority seems to give to some parts of the manuscript of Eraclius the earlier place, and it may perhaps without serious question be assigned to as early a period as the tenth or the eleventh century. Eraclius treats of many subjects. He describes the process of making glass, using lead in its composition, and he treats of its decoration and its engraving. He tells us how to polish gems, to glaze pottery, to prepare drying-oils, to make white lead, to prepare wood for painting, etc. He says: "If you wish to make the white which is called ceruse, take lead plates and put them into a new jar, and so fill the jar with very strong vinegar and cover it up, and set it in some warm place, and leave it so for a month; then open the jar and put what you find adhering to the strips of lead into another jar, and place it upon the fire, and keep stirring up the color until it becomes as white as snow."[2] This description of the methods employed is very similar to those given by Theophrastus, Vitruvius, Pliny, and Dioscorides, and is open to the same objections. The product would seem to have been lead acetate and not white lead; or at least a mixture, in which the acetate was in large excess. The directions for drying would lead us to infer that the lead when taken from the jar contained a notable quantity of moisture, which must have held lead acetate in solution. It is interesting to note that Eraclius in another place recommends the use of decomposing dung to furnish heat in aid of chemical action. He describes a process for making a green as follows: "Mix vinegar with strong honey, and then cover up the vase itself in very hot dung, and so

[1] See Mrs. Merrifield, Original Treatises, etc., vol. i. p. 1 *et seq.*

[2] Eraclius, De Coloribus et Artibus Romanorum, translated by Mrs. Merrifield in Original Treatises, etc., vol. i. p. 236.

take it out after twelve days have elapsed.[1] This recipe occurs in the "First Metrical Book," of Eraclius, which is acknowledged to be the earliest portion of the manuscript, and is thought by many authorities to antedate Theophilus and the manuscript entitled "Mappae Clavicula."

The use of white lead was probably very general in the time of Eraclius. Artists painted their pictures upon panels of wood, and not upon canvas as is the custom to-day. The preparation of these panels was a work of great care, as it was not only necessary to secure a perfectly smooth surface, but the wood must be protected from the action of the atmosphere. Eraclius describes the methods employed to secure these conditions as follows: "First make the wood very smooth, by scraping it and rubbing it down with *shave grass*. If you cannot shave down the inequalities in this way, and do not wish to cover it with leather or with cloth, grind dry white lead upon a stone, but not so finely as if you were going to paint with it; then melt wax over the fire in a vase, add tiles finely ground, then mix it with the white lead you have ground, stirring it frequently with a stick, and so let it cool; then heat an iron, and with it melt the wax into the little fissures until they are level, and then scrape the rough parts with a knife. When you have made it smooth mix plenty of white lead, very finely ground *with linseed oil*, and lay on an excessively thin coat of it wherever you intend to paint with a brush, made of ass's-hair, adapted for that purpose. When this is done lay on, as you did before, another and thicker coat of it, — not thicker by having a greater quantity of color, but by having less oil in it; for you must take care never to lay on the color *too fat*, for if you do this, and lay on a great deal of it, when it begins to dry wrinkles will form on the surface of it."[2]

[1] Eraclius, De Coloribus, etc., Original Treatises, etc., vol. i. p. 194.
[2] Ibid., vol. i. p. 230.

Eraclius recommends the following method for preparing a column for painting: "First let it dry perfectly in the sun, or before a fire; now take white and grind it finely with oil upon a marble slab; afterwards lay on the column two or three coats of that white with a broad paint-brush; then rub very stiff white over it with your hand, or with a brush, and let it remain a short time. When tolerably dry press your hand strongly over the whole surface, drawing your hand towards you. Continue this until it is as smooth as glass. You will then be able to paint upon it with all colors mixed with oil."[1] In this manuscript there may be found directions for glazing earthenware with lead, for making lead-glass, and for the preparation of oil for painting, its siccative qualities being improved by the addition of white-lead, and by subjecting it to heat. Eraclius describes at some length formulae to be employed in mixing colors to produce certain shades and tints, and it is noteworthy that he invariably recommends the use of white lead as the base of all colors.[2]

The most voluminous and satisfactory of all existing copies of the manuscripts of Theophilus was found in 1844 by Mr. Robert Hendrie, in the collection known as the Harleian manuscripts, preserved in the British Museum. Hendrie translated and published this copy in 1847.[3] In 1843 the Count Charles de L'Escalopier published in Paris a translation of the copy of Theophilus found in Trinity College library, Cambridge, with an introduction and notes by M. J. Marie Guichard.

As above remarked, Lessing places Theophilus as early

[1] Eraclius, De Coloribus, etc., translated by Mrs. Merrifield in Original Treatises, etc., vol. i. p. 230.

[2] Ibid., vol. i. p. 256.

[3] Lessing proposed to publish the Wolfenbüttel and Leipsic copies, but his death occurred before his intentions could be carried out. After Lessing's death Leiste edited it, and published it in the sixth volume of his "Collected Works of Lessing."

as the ninth century, while Guichard contends that we must not ascribe an earlier date than the twelfth or thirteenth centuries; but Hendrie argues at length in favor of an earlier period. He says: "While Greece was the painter of the continent, Tuscany the enameller, Arabia the worker in metals, Italy the jeweller, France the worker in glass, Spain the chemist, industrious Germany anxious in acquiring dexterity or knowledge in all, — when all these artists had constructed and were adorning the Church of St. Mark at Venice, and were occupied in western Europe in writing or painting (the terms were then synonymous) the sacred histories in the church, so that the illiterate might read the examples set before them, the treatise, 'Diversarum Artium Schedula,' came forth." [1] Hendrie therefore ascribes to the early half of the eleventh century the production of this remarkable work, which seems to be justly entitled to be termed "An Encyclopædia of Christian Art in the Eleventh Century."

In his preface Theophilus styles himself "A humble priest, servant of the servants of God, unworthy of the name and profession of a monk." He exhorts those in whose hearts God has placed the desire to explore the vast field of the divers arts to read this "Book of Various Arts" with a tenacious memory, and to embrace it with an ardent love, promising, if it is carefully perused, that there shall be found out whatever Greece possesses in kinds and mixtures of various colors; whatever Tuscany knows of in mosaic work, or in variety of enamel; whatever Arabia shows forth in work of fusion, ductility, or chasing; whatever Italy ornaments with gold, in diversity of vases, and sculpture, of gems, or ivory; whatever France loves in a costly variety of windows; whatever Germany approves in works of gold, silver, copper, and iron, of woods, and of stones.[2]

[1] Hendrie, Translation of Theophilus, p. 16.

[2] Ibid., p. 51.

The manuscript of Theophilus is indeed "An Encyclopædia of Art." He treats of the manufacture of colors, white lead, vermilion, red lead, azures, and greens; of grinding and mixing of colors in oil, and in gums; of the manufacture of glue; of the preparation and use of linseed oil in painting; the manufacture of white and colored glass, transparent and opaque; the building of organs; the construction of foundries, with particular directions for the building of furnaces for various purposes; the manufacture of tools; the founding of bells, and the manufacture of musical cymbals, etc. In his description of the manufacture of white lead Theophilus refers to a previous description of the manufacture of what he terms *salt-green,* which is as follows: "Take oak wood, as long and as large as you like, and hollow it in the form of a box; then take copper and thin it into leaves as broad as you desire, so however that its length may cover the breadth of the hollow wood; after this take a plate full of salt, and pressing it down strongly cover it with charcoal for a night, and on the morrow grind it carefully upon a dry stone, and when you have taken some slender twigs place them together in the same hollowed wood, so that two parts of the hollow are below and the third part is above them; and thus coating the copper-plates on both sides with pure honey, sprinkling over them the ground salt, you will fix them, joined together, upon the twigs, covering carefully with another wood fitted for this, so that no vapor can come out. Afterwards make an opening, to be bored in an angle of the same wood, through which you can pour warm vinegar, or hot urine, so as to fill a third part of it, and then close the passage. You should put this wood in such a place that *you can cover it with stable dung.* After four weeks raise the covering, and scrape off and keep whatever you find upon the copper, and again replacing it cover it as above.[1]

[1] Hendrie, Translation of Theophilus, p. 47.

The next recipe describes a method for making Spanish-green, in which the plates of copper are not treated with salt and honey, but scraped carefully on both sides, and put into the box with pure and warm vinegar "in the order above," referring to the previous recipe for making salt-green. Theophilus omits all further directions for treatment; but says, "after two weeks examine and scrape it," evidently intending that the treatment shall be as in the previous recipe for making salt-green, namely, burying in stable dung.

The recipe immediately following begins — "But in making ceruse make for yourself plates of lead thinned, and placing them together dry in a hollowed piece of wood, *as the copper*, hot vinegar or urine being poured over it, cover it; then after a month raise the cover, and taking away whatever white there is replace it as before."[1]

In the recipe for making Spanish-green Theophilus omits to direct that the receptacle in which the copper and vinegar are placed be buried in stable dung; and he also omits this necessary direction in the recipe for making white lead. After describing the method in which the copper and the lead should be prepared and placed in the hollow wood he refers to the preceding recipes for directions for further treatment. It appears therefore that the direction to bury the hollow wood in stable dung is omitted merely to save a tedious repetition. Accepting this suggestion we have in this description the recommendation of the use of fermenting stable-litter as a source of heat, and possibly as one source of the carbon dioxide necessary for the production of true white lead. There can be no question of the use of stable-litter for similar purposes in the manufacture of salts-of-copper, as Eraclius, as well as Theophilus, distinctly recommends it.

[1] Hendrie, Translation of Theophilus, p. 48.

Theophilus gives many formulae for mixing colors to produce different shades and tints, and as Eraclius, recommends in every case white lead as the base, presumably on account of its great opacity. He suggests that three coats of paint be applied in painting upon wood, and that it should be dried in the sun. Ceruse, minium, and carmine he directs should be ground and laid on with white of egg.[1]

The author of "Mappae Clavicula" describes the process of making white lead as follows: "Cast lead into plates or sheets, then suspend over strong vinegar. After it is corroded scrape it off and wash well." Another method proposed directs that lead cast in plates be placed in a new pot partly filled with vinegar, the pot is then covered closely and put in a *warm place,* and left undisturbed for a month. Upon opening the pot the corroded lead should be removed and thoroughly washed, "when it will become as white as snow."[2]

Some years since, Didron found in a convent at Mount Athos, in Greece, a manuscript, portions of which the monks claimed to be unquestionably of Byzantine origin, and copied as early as the tenth or the eleventh century. The manuscript had received additions from time to time, and copies had been frequently made from it for distribution to other religious houses. The manuscript was preserved with miserly care, and Didron experienced great difficulty in obtaining a copy of it. The title of this work is "The Guide to Painting," by Dionysius, monk, of Fournand d'Agrapha.

[1] Hendrie, Translation of Theophilus, pp. 3, 35.

[2] Archæologia, vol. xxxii., article by Phillips. A curious recipe: "To Make a Picture Water-proof" is found in this MS. The author says: "Spread the oil called *cicinum* over the picture in the sun, and it will be fixed so it can never be effaced." Cicinum, the oleo cicinum of the Egyptians, from Ricinus communis, our castor-oil plant, is a very slow-drying oil, hardly classed among the drying-oils by those familiar with its properties, and would scarcely be used now for such a purpose.

The following directions are found in this manuscript under the title, "How to Make Ceruse": Take lead cut into thin pieces, and suspend these pieces in a pot filled with vinegar; close tightly this pot, and bury it in fresh dung in a warm place. At the end of ten or fifteen days take up the pot and throw the lead upon a stone and grind it; put the product in a large vase and dry it, and you will have a good ceruse. The author states that ceruse is better if it is ground in nut-oil.[1]

The descriptions of the methods employed in the manufacture of white lead found in these old manuscripts form a connecting link between the methods described by the old Roman and Greek authors and those observed in modern practice. While in a general way they resemble the methods recommended by Theophrastus, Vitruvius, and Pliny, so much so as to lead to the inference that the differences are only such as would naturally occur in their transmission by copying from manuscript to manuscript through ten centuries, yet Theophilus and Eraclius both imply that dung was used as a means of producing the necessary heat, and both authors mention the use of linseed oil as a vehicle for spreading the paint. The same objections may be made to the methods of Theophilus and Eraclius as has been noticed respecting those of the earlier writers, the absence of any clue to provisions for supplying carbon dioxide. The same suggestion may be made to cover the objection in this case. The vinegar was probably largely contaminated with substances which produced by their decomposition carbon dioxide in notable quantities. There can be no doubt respecting the product of the operations described

[1] M. Didron et Dr. Paul Durand, Manuel d'Iconographie Chrétienne, Grecque et Latine, traduit du MS. Byzantine, etc. (Paris, 1845), pp. 34, 48. This manuscript is probably a copy of an older MS., compiled by the monk Dionysius from the works of Manuel Pauselinos, of Thessalonica, a painter who flourished in the twelfth century. A recommendation of *le fard du Venise*, or *le bon fard du France*, is probably a modern interpolation.

by Theophilus and Eraclius. Lead acetate might be made to answer as a pigment by mixing it with white of egg; but it would certainly fail to remain white, and would be devoid of opacity, and utterly useless as a pigment if mixed with linseed oil. Theophilus recommends that ceruse, minium, and carmine be ground in and laid on with white of egg; but Theophilus was fully acquainted with the characteristics of linseed oil, describes the method of its manufacture, which is precisely like that in use to-day, and recommends its use in grinding and applying pigments. Eraclius, who is thought by some to have written earlier than Theophilus, gives elaborate directions for grinding white lead in linseed oil, and recommends its use in spreading this pigment. There can scarcely be a question that in the time of Theophilus and Eraclius true white lead was produced, and was used in painting in notable quantities. It cannot be supposed that any of the writers and compilers upon this subject heretofore quoted were practically familiar with the details of all the processes described by them. We have seen that Alcherius, seventeen hundred years after Theophrastus, and many centuries subsequent to Eraclius, passed the greater portion of his life in journeying from place to place and collecting his recipes. The work must have been much easier in his time than in the period when Theophrastus and Eraclius flourished. The methods described by Theophilus, Eraclius, and the author of "Mappae Clavicula" are purely empirical, and were collected by them in their travels in southern Europe, or copied from manuscripts and recipes secured in their visits to Italian monastic establishments, where they had survived through all the vicissitudes of the dark ages.

Eastlake refers to the interesting fact that a connection has always existed between Materia Medica and materials used in painting. A reason for this connection may be

traced, perhaps, if we remember that in ancient times the salts-of-lead, and other substances used in painting were, as now, also employed as remedial agents. The ancient accounts of the preparation of white lead, red lead, litharge, and other pigments, are generally found in works treating principally of Materia Medica; and the early references to these substances are not limited to their use in medicine, but indicate also their employment in decorative art. The Greeks applied the word *pharmakeia* to substances commonly used in painting, and the Romans used the word *medicamen* in the same sense.

The monks preserved during several centuries a knowledge of the arts and sciences which was absolutely destroyed in secular life, and the establishment of monastic dispensaries, and the cultivation of the sciences of chemistry and botany rendered the friars familiar with the properties, as well as with the manufacture of many substances common to the arts of medicine and painting. The monks for many centuries were not alone the only manufacturers of many pigments, but they were also the only painters, practising the latter art in common with others in the construction and in the decoration of their establishments. Their monasteries were supplied with furnaces and appliances for the manufacture of glass, and with chemical and other apparatus for the preparation of pigments and remedial agents. For many centuries pigments and materials used for painting were only to be obtained of the monks; but in the thirteenth century they seem to have been gradually relinquishing their monopoly, for at this time the limited demand for these substances was principally supplied by the apothecaries.[1]

The dealers in drugs and herbs used in medicine, and of pigments and materials used in painting, were called *pigmentarii, seplasiarii, pharmacopolae, medicamentarii,* in

[1] See Eastlake, History of Painting, introduction, p. 4 *et seq.*

Rome, in the middle ages. The word *apotheca* signified any kind of store, or warehouse, and the keeper was called *apothecarius*.[1]

Eastlake refers to the purchase, in 1274, of painting-materials to decorate St. Stephen's Chapel, of Roberto de Hakeneye, *speciario*, and in a manuscript dated Turin, 1315, colors and painting-material are mentioned as having been bought of an apothecary.[2] Tambroni, in his introduction to the translation of the manuscript of Cennino Cennini, says that the painters of the time of Cennini — 1350–1437 — purchased their pigments of the apothecaries.[3]

In later times materials for painting were unquestionably sold by the apothecaries. An old black-letter treatise in the British Museum refers to the *poticaries* "for all such colours, and other things as are mentioned and contained in this present 'Booke of Limming.'"[4] Huet says: "The Dutch send to France drugs, as well for medicine as for painting," and "they dispose of in Spain a considerable quantity of drugs, both for the apothecaries' and the painters' use."[5]

[1] Beckmann remarks that "it would be a mistake if in the writings of the thirteenth and fourteenth centuries, where these expressions occur, we should understand under the latter apothecaries such as ours are at present." He is of the opinion, however, that the physicians in Africa first began to give up the preparation of their prescriptions to other men, and that this was customary as early as the eleventh century. In many cases the first apothecary-shops were established at the public expense, and belonged to the magistrates. The first English apothecary flourished in 1345. In France no mention is made of them until 1484. In Germany they are noticed at about the same date, though some have maintained that they existed as early as the thirteenth century. They were probably recognized as a separate class much earlier south of the Alps. See Beckmann, History of Inventions, vol. i. p. 328 *et seq.*

[2] Eastlake, History of Painting, vol. i. p. 11.

[3] Cennini, Treatise on Painting, translated by Mrs. Merrifield, introduction by Tambroni.

[4] A Very Proper Treatise, wherein is breefely sett forth the Arte of Limming, imprinted at London, in Flete Street, within Temple Barre, at the sign of the Hunde and Harre, by Richard Totthill, 1581.

[5] M. Huet, A View of the Dutch Trade (London, 1722), pp. 78, 87.

The connection between Materia Medica and materials used in painting has persisted until the present day, when, except in populous centres where establishments expressly devoted to this branch of business may be found, materials for painting are supplied by the apothecaries.

CHAPTER XI.

WHITE LEAD, TWELFTH TO SEVENTEENTH CENTURY.

AN inquiry into the development of the manufacture and of the use of white lead, from the eleventh to the seventeenth century, shows the progress of modern civilization. Where this substance is most in favor, whether for the expression of the highest type of art, or for the decoration of public or private buildings, we find the highest type of culture and refinement. We can perhaps arrive at a better understanding of the development of this industry during the period above referred to, if we briefly consider the changes that occurred in the social condition of Europe, and glance at the development in trade and commerce which began at the time of the great Revival in progress in the eleventh century.

The character of the architecture of the early centuries of the middle ages was generally simple and primitive. The first church built of stone in the British Islands was erected about the beginning of the fifth century by Ninian, a British priest, on a small island on the coast of Galloway. The second was founded at York about 628, by Edwin, king of Northumberland, who died before its completion. It was finished by Bishop Wilfrid, who covered the roof with lead and filled the windows with glass, "which, while it excluded the birds and the rain, admitted light into the church." [1] Secular architecture

[1] Macpherson, Annals of Commerce, vol. i. pp. 214, 238.

showed no improvement until the fourteenth or fifteenth century. The castles, which were the residences of the nobility, were mere strongholds erected especially for defence; they were built upon commanding sites, were provided with walls of immense thickness, strong gates, and the openings, especially in the lower stories, were few, and were mere slits or loopholes; those in the upper stories were but little better, unglazed and closed perhaps by a shutter of stone. In later times other buildings, more convenient and appropriate as habitations, were erected and connected with these keeps or towers, the whole forming a fortified square with a court in the centre. These connecting buildings usually had larger windows on the side facing the court, but the openings on the outer side were narrow. In still later times, the residences of the great nobles were strong buildings of stone or brick provided with towers and battlements, and forming one or two sides of a square, the other sides being occupied by the stables and outbuildings.[1]

The dwellings of the gentry in the fifteenth and sixteenth centuries were rarely of more than two stories, — the lower one prepared for defence and provided with narrow apertures, while access to the upper was by means of a stairway built on the outside. The lower story was occasionally built of stone, but generally these houses were entirely constructed of heavy timber, the interstices being filled with plank and cement. The interior walls at first were bare, not even plastered; but later the principal rooms in the houses of the wealthy were hung with tapestry. Chimneys were not generally introduced until the fourteenth and fifteenth centuries; at this period glass windows were uncommon except in the churches, palaces of the royal family, and in the houses of the more powerful nobles. As late as the fifteenth century glass windows

[1] See Hallam, Middle Ages, vol. iii. p. 331.

were considered as movable furniture.[1] The furniture of the houses of the wealthy was of the simplest description. Chairs were rarely seen, and mirrors were almost unknown. The rich possessed one or two beds, but the custom at this time was to sleep upon a mattress placed upon the floor. In the twelfth and thirteenth centuries the dwelling-houses in London were rarely of more than one story. The dwellings of the middle and lower classes were of wood or of wattles, generally of one story, and without chimney or glazed windows. "At this early period," observes Walpole, "there was no medium between castles and hovels." [2]

Such a condition of domestic architecture furnished little encouragement for decoration, and we find few references to the use of pigments for decorative purposes for private dwellings. The exteriors of some of the castles were whitewashed, and a manuscript of the period referred to by Mrs. Merrifield indicates that they were occasionally painted. The interiors of public buildings were frequently elaborately decorated. There is preserved in England the "Rotuli Litterarum Clausarum" or Close Rolls, a series of parchment rolls upon which are recorded the mandates, writs, and letters of a private nature, of some of the early kings of England. The orders on these rolls begin with the sixth year of the reign of King John, — 1204. Many curious entries refer to the purchase of pigments and materials used for painting, and indicate the character of the work done, as well as its cost. In the twelfth year of the reign of Henry III. (1228) an order to the treasurer commanded the payment to a certain painter of twenty shillings for painting the great exchequer-chamber. Walpole thought the decoration must have been more elaborate than the work of a house-painter, as at that

[1] Hallam, Middle Ages, vol. iii. p. 331.

[2] Horace Walpole, Anecdotes of Painting in England, vol. i. p. 22.

time the sum would be a large one for simply painting wainscot. In 1236 the same sovereign ordered that his great chamber at Winchester "be painted a good green color, so as to resemble a curtain," and in the great window of the same chamber he directed this motto to be painted: "He who gives not what he has receives not what he wishes for." The king's small wardrobe was likewise ordered to be painted green "like a curtain." In the same year the "bordure" of the king's and queen's seats in the chapel of St. Stephen at Westminster were ordered to be painted green. This was a favorite color with the monarch; for two years later the sheriff of Southampton was directed to cause the chamber at Winchester to be painted green. Another item shows the use of oil in painting. The treasurer and chamberlain are directed to pay to Odo, the goldsmith, and Edward, his son, one hundred and seventeen shillings and ten pence for oil, varnish, and colors bought of them, and for pictures made in the queen's chamber at Westminster.

The decoration of interiors at this period consisted principally in painting upon the walls pictures representing historical or sacred subjects, but wainscot was sometimes painted. Columns were frequently decorated in this manner, and painting to represent a curtain is often referred to. This style of decoration was now first used in the houses and castles of the nobles. The great halls and rooms were hung with tapestry or decorated with colors, and their ceilings were painted green or blue and studded with stars.

In 1292 the chapel of Saint Stephen was repaired and painted. The wages of the principal painter at this time was 14*d.* per day; two subordinates, Andrew and Giletto (Italians), were paid 6*d.* and 8*d.* per day. White lead, red lead, and oil are repeatedly mentioned in the accounts of the period. White lead was charged at 1½*d.* per pound,

red lead at 2*d*., and oil at 5*d*. to 6*d*. per "pottle." Edward III. destroyed the chapel of Saint Stephen in 1352, and in rebuilding it more magnificently pressed all the painters in Kent, Middlesex, Essex, Surrey, and other counties into service to assist in its decoration. Among the items for material for decorating this chapel, the following appear: —

19 lbs. white lead for priming	@ 4*d*.	£0	6*s*. 4*d*.
4 Flagons of Painter's Oil		0	16*s*. 0
62 lbs. Red Lead	@ 5*d*.	1	5*s*. 10
½ lb. Red Lead			8

Item: To John Lightgrave.

51 lbs. White Lead	@ 2½*d*.	£0	10. 7½
53 " White Lead	@ 3½*d*.		15. 5
43 " Red Lead	@ 4*d*.		14. 6
3 " White Lead			1. 0

Eastlake directs attention to the large quantities of oil purchased at this time, and thinks that the character of the decoration did not consist merely of historical pictures or those illustrating sacred subjects, but that walls, columns, and ceilings of palaces and public buildings were painted in colors.[1]

In continental Europe during this period the state of society was much the same as in England. The character of secular architecture, except in some important and growing walled cities and towns, differed very little from that described as prevailing in Great Britain.

A great revival of commerce followed the inauguration of the Crusades. After the dismemberment of the Roman Empire, the little commerce which existed with the East was principally carried on through Constantinople. The Italian cities, however, and more especially Venice, began in the ninth or tenth century to push their trading-voyages

[1] See Eastlake, History of Painting, vol. i. pp. 50, 61; Hendrie, Translation of Theophilus, pp. 71, 72; Mrs. Merrifield, Original Treatises, etc., p. 24.

to the ports on the southern shore of the Mediterranean. But the revival began with the Crusades, which not only revolutionized commerce, but produced a marked change in the social condition of the times.

From the beginning of the twelfth century great throngs of pilgrims followed the valley of the Danube on their way to the Holy Land, while other hosts reached the shores of Asia Minor by sea from ports on the Mediterranean. The contact of the Northern pilgrims with the luxury of the Orient developed in them new tastes and desires which they were enabled to gratify at a moderate cost in the bazaars of the East.[1]

The Italian cities were the first to feel the force and effect of the great social and commercial revolution produced by this stream of travel. Venice, Genoa, Pisa, and afterwards Florence, became the seats of great commercial houses, who sent their galleys into the ports of the civilized world. In 1202 the Venetians supplied the French crusaders with a fleet of more than two hundred and eighty vessels, to transport them to the Holy Land. The siege and capture of Constantinople by the Venetians, assisted by the Crusaders, gave the entire trade of the Mediterranean to the merchants of Venice. The Venetians retained this trade for nearly three hundred years; they engaged largely in the manufacture of silks and of other stuffs, and their products were celebrated throughout the world. In 1492, according to Macpherson, their commerce was equal to that of all the rest of Europe.[2]

The Italian merchants established their factories or trading-houses in every principal port on the Mediterranean. They waged war, made treaties, and wherever possible secured commercial advantages over their rivals. They monopolized the trade of the Orient, and controlled the

[1] See Pigeonneau, Histoire du Commerce de la France, first pt. p. 126 *et seq.*

[2] Macpherson, Annals of Commerce, vol. i. pp. 368, 719.

productions and manufactures of Persia and of other Asiatic nations, and distributed them throughout Europe.

The lack of regular means of transportation, the interrupted and dangerous intercourse between merchants of different nations, owing to piracy on the sea, and robbery upon the highways, led, in very early times, to the establishment of great fairs, where merchants from distant countries could meet periodically for the exchange of their commodities. In 472 fairs were appointed in Italy; about the year 800 Charlemagne established fairs at Aix-la-Chapelle and at Troyes.[1] The manufacture of cloths had become well established in Flanders in the twelfth and thirteenth centuries, and the Italian merchants met the Flemings at the great fairs held at Champagne in France, and exchanged the spices of the Orient for the stuffs of Flanders. Many Italians afterwards visited the Low Countries, making their way over the Alps and through France, but soon adopted the easier and nearer route through Germany, by Basle and Cologne, or by Nuremberg. This exchange of commodities increased until the trade between these people attained a high degree of prosperity. Finally, Venice and Genoa determined to organize a regular annual service by sea with the Low Counries, and sent their galleys loaded with the products of the Orient to Antwerp. It is impossible to fix a date for the inauguration of this important event; but in 1224 the records of the city of Antwerp show the presence in its port of a Genoese galley, and there is no doubt of the existence of regular service between Venice and Antwerp in 1318, as in the month of May of that year two Venetian galleys entered the port of Antwerp, and in February, 1319, three galleys arrived in the Scheldt from Venice. The cargo of

[1] Macpherson, Annals of Commerce, vol. i. pp. 220, 250. The fairs at Troyes are memorable for the establishment of the system of weights which is used to-day for weighing gold, silver, and precious stones.

one of these galleys consisted in part of *drugs and colors.* According to Tambroni, the Venetians at this early day manufactured or prepared in Venice drugs and colors, which formed no inconsiderable portion of their trade with northern Europe.

Many Italian commercial houses had resident agents in the Low Countries at this time. Pegolotti, an agent of the house of Bardi, resided at Antwerp from 1315 to 1317. Antwerp became the principal emporium for the exchange of the productions of northern Europe for the silks, spices, dyes, and colors of the Orient, and the Italians retained a monopoly of this valuable trade until the discovery by the Portuguese in the sixteenth century of the passage to the Indies by the Cape of Good Hope.[1]

For information respecting the methods employed in the manufacture of white lead during the thirteenth, fourteenth, fifteenth, and sixteenth centuries, one must refer to ancient manuscripts; but, unlike those noticed in the preceding chapter, the dates of these manuscripts are sometimes definitely known, and their authorship and history are not entirely subjects of conjecture. The methods employed by artist-painters during this period in preparing and in mixing their pigments, were copied into books kept for that purpose and carefully preserved for use in the studio. Many painters had methods and formulae of their own discovery, or invention, and guarded their secrets with jealous care, imparting them only to their apprentices, under the strictest injunctions of secrecy. The Flemish and the Italian painters very generally ground and prepared their colors with their own hands, perhaps to secure absolute purity and uniformity, and to guard the secret of their preparation; and, possibly, because at that

[1] Mrs. Merrifield, Original Treatises, etc., vol i. p. 23; Cennino Cennini, introduction by Tambroni, p. 37; Heyd, Histoire du Commerce du Levant, vol. ii. p. 718 *et seq.*

time the manufacture and sale of some of the pigments had not become a thoroughly established industry. These manuscripts, or *secretii*, as they were termed, were used by the painters as memorandum-books, and, from time to time, as new recipes would fall into the hands of the compiler, or new discoveries or inventions were made, they were entered; there is frequently found, therefore, in a collection of old formulae and recipes, others of much more modern origin.

Many of these *secretii* have been preserved, and are treasured in the libraries of Europe. An examination of them shows that while several white pigments are referred to as having been used by the painters of that day, the white universally recommended, and generally employed, was white lead. It is mentioned under many names, and with many variations of orthography. In Italy, it was termed *blacha, blachi, biaca, biacca, biacha, bracha, bianco di piombo, ceruse, cerusa, cerussa, cerusam, cerusia, cirocis, ceruza, album plumbum, albo plumbum, albo plombo.* In Germany, it was called *abit, abot, aboit, bleyweiss;* in France it was known as *ceruse, ceruse d'Allemagne, ceruse de Krems, blanc de Venise, blanc d'argent, blanc d'écailles, blanc en écailles.* In Spain, it was called *blanquet* and *albayalde;* a manuscript of the fourteenth century, preserved in the British Museum, refers to white lead as *minium album.* In Arabic, it was known as *assidegi* or *assidagi.*[1] With the earlier writers, and even in a manuscript of the seventeenth century, it is classed among the colors which do not dry well, notwithstanding many authorities recommend its addition to linseed oil to increase the siccative qualities of that vehicle, universally used in modern times for spreading pigments. Christopher

[1] See Bourrassé, Dictionnaire d'Archéologie; also Mrs. Merrifield, Original Treatises, etc.; also Petri Andreae Matthioli, Commentarii Dioscoridis De Medica Materia Venetiis, 1558.

Ballard mentions, in 1682, as a great secret, the addition of turpentine to white lead to make it dry well.

Among the manuscripts collected by Le Begue is one by Petrus de Sancto Audemaro, who lived in the north of France, late in the thirteenth or early in the fourteenth century. Some of the formulae of this author are considered to be much older than his time, among which is the following: "White and green colors, without salt, are made and tempered as follows: pour strong vinegar into a vase and place twigs across it inside the vase, and then place strips of lead, and other strips of copper or brass, suspended in the air by means of twigs, so as not to touch the vinegar or each other; then close the vase very carefully and lute it with clay or cement or wax, so that there may not be the least hole through which the vinegar may exhale. Then cover it with horse-dung, and after thirty days, on account of the acidity of the vinegar or wine (for the wine, on account of the heat of the dung, will become vinegar), the copper or brass will be found to be turned green, and the lead white. Take the white lead, dry it, grind it, temper it with wine to paint on parchment, and mix it with oil to paint on wood."[1] The vinegar recommended here is probably a mixture of wine lees and wine, or vinegar in which both the vinous and acetous fermentation had begun, but was yet incomplete. Saint Audemar says, "The wine, on account of the heat of the dung, will become vinegar." The method, therefore, so far as the production of acetous vapors and carbon dioxide is concerned, is precisely like that now in use at Klagenfurth, in Carinthia. Saint Audemar also directs that the vases containing the lead and acid be buried in *beds* of *dung;* and in describing the manufacture of "salt-green," which was produced by exposing plates of copper, smeared with salt, in vases containing vinegar,

[1] Saint Audemar, De Coloribus Faciendis, in Mrs. Merrifield's Original Treatises, etc., vol. i. p. 120.

and buried in heaps of stable-litter, he recommends that the operation be conducted in a horse-stable. This author also suggests that heaps of grape-skins from the wine-press be used as a ferment instead of horse-dung, and says it will produce the same result.

Eastlake and other authorities are of the opinion that the date of the manuscript of Saint Audemar, cannot be later than the end of the thirteenth, or the beginning of the fourteenth century; and it is also thought that many of his recipes are much older than his time. If, therefore, there may be a question as to the use of stable-litter, as a ferment, in the manufacture of white lead in the time of Eraclius, and Theophilus, there can be no doubt of the employment of this source of heat in the thirteenth or early in the fourteenth century. An additional evidence that ferments were used at a much earlier period as a source of heat, and possibly of carbon dioxide, may perhaps be found in the recommendation of the use of grape-skins, or refuse from the wine-press, as a substitute for stable-litter. It is extremely probable that the utilization of heaps of fermentable material for similar purposes had been practised during many centuries.

Cennino Cennini, a painter, who lived in the latter part of the fourteenth and early in the fifteenth century, left a valuable manuscript, which embodies the experiences of two generations of great artists in the preparation and in the mixing of colors. Only three copies of this manuscript are known to exist. The most complete was discovered among the manuscripts of the Vatican, in the early part of this century, by Tambroni. It was translated into Italian by him, and afterwards into English by Mrs. Merrifield. Cennini says: "Biacca (white lead) is prepared chemically from lead, and is a strong and brilliant color. It is sold in cakes of the shape of drinking-glasses; always select that kind the top of which is in the form of a

cup. Grind it with water and it will bear any tempera."[1] It was customary, it seems, in that early day to mould white lead into small conical loaves, by pouring the pulp into earthen vessels, and drying it in a heated room.

This method of preparing white lead prevailed in some European factories until very recent times. Very white, selected lead, was put up in conical loaves, or shapes, and covered with blue paper. The custom of grinding white lead in oil by the manufacturer is of very recent date; formerly, all lead was sold in the dry state, and the painter, or his apprentices, mixed the lead with oil and ground it in hand-mills, or on a marble slab. A manuscript preserved in the library of the convent of Saint Salvatore, in Bologna, and entitled "Segretti per Colori" is a collection of recipes for making and preparing colors for painting, dyeing, etc. The name of the author is unknown, but the date of the manuscript is considered to be about the middle of the fifteenth century. The compiler describes the manufacture of white lead as follows: "Take leaden plates, and suspend them over the vapor of vinegar in a vase, which, after being luted, must be placed in dung for two months; then scrape away the matter that you will find upon the plates, which is the white lead. Do this until the plates are consumed." The author of this treatise adds the following instructions for purifying ceruse: "Take ceruse, put it in a clean jar, which should be placed over the fire, stir the ceruse continually with a stick, and it will become white." He also adds a recipe for preparing ceruse for painting, in which he directs that the ceruse should be well washed several times in hot water; then gum-arabic and white incense are to be ground together in clean water, the white lead added, and the whole finally ground together,— gum-water being added "as you think it needs."[2]

[1] Cennino Cennini, translated by Mrs. Merrifield, p. 32.
[2] Mrs. Merrifield, Original Treatises, etc., vol. ii. pp. 326, 484.

A manuscript entitled "Secreti Diversi," preserved in the library of San Marco, at Venice, is another collection of recipes. Its date is considered to be early in the sixteenth century. The writer recommends the use of "good white lead" if you wish to make a good white, and asserts that horse-dung is the best ferment.[1]

Mrs. Merrifield found in the library of the University of Padua, a manuscript entitled "Ricette Per Far Ogni Sorte Di Colori," which she states to be certainly Venetian, and to have been compiled during the middle of the seventeenth century. It contains a description of a process for making "a very pure white lead," which is the first departure from the principles described by Theophrastus, nearly two thousand years before. The author says: "Take the calcined lead of the potters — litharge — in proper quantity; pound it fine; pour it through a coarse sieve of silk, and having placed it in an earthen vessel with very strong *white vinegar* (if distilled it will be better), leave it for three or four days, frequently stirring it and letting the impurities of the lead go to the bottom. Then decant the vinegar, and pour over the lees fresh vinegar, in such quantities that no odor may proceed from it, and that the precipitate may be almost black. Then take rain or well water, with the proper quantity of salt, and with this salt water precipitate the lead which is in solution, and wash it with common water until it has no more odor or savor. Then dry it by placing it on leaves of blotting-paper until it is dry."[2]

This process may have been in use many years before its description found a place in the Paduan manuscript. Many authors of the thirteenth, fourteenth, and fifteenth centuries describe the manufacture of greens by smearing plates of copper with salt and honey, and exposing them

[1] Mrs. Merrifield, Original Treatises, etc., vol. ii. pp. 610, 612.
[2] Ibid., vol. ii. p. 698.

in vases containing vinegar, which were buried in heaps of stable-litter for fifteen to sixty days; but none refer to a method of preparing white lead in which salt is used. Saint Audemar (1300?) speaks of making white lead *without salt,* but in this case he refers to a preceding recipe, in which green is made by smearing copper with salt and exposing it to acid fumes. The method recommended by the author of the Paduan manuscript may therefore have been unique, and it is interesting to note that it was revived a few years since, and patents taken out for it in England as a new invention.

Giovanni Batista Volpato, born in Bassano, in 1633, was the author of a manuscript entitled "Modo Da Tener nel Dipinger," now in the library at Bassano. Volpato recommends that white lead be ground in nut-oil, and that ground colors be kept in folded papers, or in bladders, but that white lead should be preserved in a vase with water. He warns painters that the only way to insure purity in their colors is to learn the process of their manufacture, and to prepare them for their own use, "as the vendors are accustomed to falsify everything."[1]

A manuscript now in the Public Library at Brussels, was written, in 1635, by Pierre Le Brun, a painter who probably resided at Paris. Le Brun says that ceruse is made "by putting vine-branches in butts, pouring vinegar over them, fixing sheets of lead on the top, and fastening them up air-tight." He mentions, in a list of white pigments, ceruse, *blanc de Venise,* and *blanc de plomb,* as if they were different substances. Writers of his time generally refer to Venice white lead as being the best, and it is probable that white lead, which was then manufactured in Holland and perhaps in England, was largely adulterated, and different names were given to it, each indicating a certain degree of impurity. Le Brun's recipes were

[1] Mrs. Merrifield, Original Treatises, etc.. vol. ii. pp. 740, 745.

carelessly copied or culled from untrustworthy sources. He classes white lead among the colors which do not dry well, — an unpardonable ignorance in that day. He says, moreover, that white lead is so called because it is found in lead mines. He refers to a fact which is noticed by several of the authors of these old *secretii*, the improvement in the drying qualities of colors by mixing with them ground glass. It has been suggested that if the glass had a notable amount of lead in its composition, this addition would possibly produce the effect claimed for it.[1]

Fra Fortunato, of Rovigo (1659–1711), gives the following directions for making white lead very white: "Take scales of white lead; select the finest quality; grind it well on marble, with vinegar, and it will become black; then take an earthen vessel full of water and wash your white well, and let it settle to the bottom, and pour off the water; grind it again with vinegar, and again wash it, and when you have repeated the operation three or four times, you will have white lead which will be as excellent for miniature painting as for painting in oil."[2] In later times, in the preparation of Kremserweiss, white lead was treated with an excess of acetic acid, to give it a white appearance and a crystalline texture. The effect of this treatment was to make it more hard and brittle, and when freshly broken the newly exposed surfaces had a glassy appearance. The possession of these characteristics was one of the tests the finest qualities had to undergo. At the present time the manufacturer strives to remove, so far as possible, every trace of acetic acid.

Eastlake refers to the fact that many attempts were made by artists of the fifteenth century to provide a substitute for white lead. Very many substances were tried,

[1] Mrs. Merrifield, Original Treatises, etc., vol. ii. p. 770 *et seq.*
[2] Ibid., vol. i. p. 311.

but each, after a short time, was discarded. They were exceedingly careful in the preparation of this pigment, refining and purifying it by repeated washings. Many authorities suggested its exposure to the sun, to improve its color; and when ground in oil, it was recommended that it be kept under water.[1]

These extracts from authentic documents show conclusively that the manufacture of white lead was commonly known and practised in England, Italy, France, and Flanders certainly, and probably in Germany and in other countries of Europe, during the latter part of the middle ages. The methods of manufacture described are, with one exception, based upon the principles explained by Theophrastus, Vitruvius, Pliny, and Dioscorides, and afterwards developed in the writings of Eraclius and Theophilus; but they show a continued improvement in technical knowledge, — such a development as might be expected from the material advance in civilization during the period under consideration.

[1] Eastlake, History of Painting, vol. i. p. 437.

CHAPTER XII.

WHITE LEAD IN ITALY, HOLLAND, AND BELGIUM.

IT is commonly believed that the Dutch were the originators of that method of manufacturing white lead which is termed the "Dutch process." Modern authorities very generally refer to the Dutch as the first to apply this method; some, however, say that they borrowed it from the Saracens in Spain. The period usually referred to for the establishment of the industry in Holland is the sixteenth century.

At the time of the great Revival in the twelfth century Italy took a leading place in the march of civilization and progress, and for nearly three hundred years held her position; during this period her cities increased in wealth and power, and were at the zenith of their prosperity. At this time the cultivation of the arts and sciences was revived, and she became the centre of great enthusiasm in the art of painting.

Heyd, Pigeonneau, Tambroni, and other authorities assert that the Italians had, at a very early date, a monopoly of the trade with Asia and that of the Levant, and of the drugs, colors, spices, and silks produced there, and that they established in their cities the manufacture of silks, colors, and pigments. It has been shown elsewhere that early in the thirteenth century a Venetian galley arrived at Antwerp with a cargo consisting in part of colors and drugs, and that regular service by sea between

Antwerp and Venice was established early in the fourteenth century. This trade in drugs and pigments continued for more than three hundred years. Guicciardia, writing in 1560, says: "The Dutch send cloth, wool, linen, etc., to Venice, and as late as 1518 five Venetian galeases arrived at Antwerp laden with spices and drugs for the fair there. They still," he continues, "bring from Venice silks, carpets, stuffs, and colors, both for dyers and painters."[1] It is clear, therefore, that as early as the thirteenth century the Flemings imported by sea their silks, drugs, dye-stuffs, and pigments from Venice, and that they continued to draw their supplies of these substances from Italy as late as 1560. It is probable that this trade was established much earlier than the thirteenth century, and that at the great fairs in France and Germany the Flemish weaver exchanged his cloths for the drugs and pigments of Italy.

At about the time of the arrival of the Venetian galley at Antwerp with a cargo of spices, silks, drugs, and colors, early in the thirteenth century, a few rude huts were built on a marshy piece of ground near a dam on the river Amstel, in Holland. The occupants of these cabins were a hardy race of fishermen, and their village, in time, came to be known as Amsteldam, afterwards corrupted into Amsterdam. The descendants of these fishermen for several generations followed the calling of their fathers, and the rise of Holland to commercial importance did not begin until the fifteenth century; manufactures did not flourish until the capture and ruin of Antwerp by the Duke of Parma, in the sixteenth century, when the miserable fugitives from that unhappy city crowded Amsterdam and other Dutch towns.[2]

[1] Louis Guicciardia, Description of the Netherlands, quoted by Macpherson, Annals of Commerce, vol. ii. p. 128.

[2] Macpherson, Annals of Commerce, vol. i. pp. 372, 620; vol. ii. pp. 176, 178.

Eraclius, it is claimed, was a Greek, who lived in Italy, and Theophilus, while he is thought to have been of German origin, is also considered to have travelled extensively in Italy and southern Europe, if not to have resided there. Tambroni indeed claims that Theophilus was certainly an Italian, while the author of the manuscript entitled "Mappæ Clavicula," if not an Italian, had either travelled in Italy and gathered his recipes from the Italian monks, or had obtained access to other and older Italian, Roman, or Grecian manuscripts, and thus become familiar with Southern methods.

These authors rarely refer to Arabian sources for their information, but the places named are generally Italian, and the terms used are of Italian origin. In his introduction Theophilus says: "If you carefully peruse this you will know whatever Greece possesses in the preparation of colors, Italy in gold ornaments, vases, and gems," etc.[1] In his time, therefore, Greece and Italy were famous for their knowledge of the preparation of pigments and of the art of decoration. Arabia is referred to for excellence in working of metals, but Spain is not mentioned. Copies of these manuscripts were undoubtedly common in Europe at this time. Their rarity now is due to the disturbed condition of society in the middle ages, and to the devastation committed by the early reformers, who in their fanatical zeal condemned and destroyed all illuminated and other manuscripts wherever found.[2]

The modern method of manufacturing white lead did not originate with the Dutch. The description in the manuscript of Theophilus varies in no important particular from that used by the Dutch in the seventeenth century, even to the use of stable-litter. Objection may be made to this statement, that Theophilus did not secure

[1] See Theophilus, Divers. Artium Schedula, translated by Hendrie.

[2] Walpole, Anecdotes of Painting, vol. i. p. 42.

the necessary carbon dioxide from the decomposing dung, neither did the Dutch in the seventeenth century depend upon the decomposition of the ferment for this element, but added to the vinegar in the pots wine lees, bits of marble, and other substances capable of producing this necessary factor. The description given by Theophilus is applicable to the manufacture of white lead in a small way only, but at that early period, and for some centuries later, it was the custom for painters to prepare their own colors, and the use of white lead was extremely limited; but the process described by Theophilus is capable of an easy extension, and any increased demand would naturally suggest an enlargement of the apparatus. Theophilus is not alone in the suggestion of the use of stable-litter to facilitate chemical action. The manuscript found at Mt. Athos, attributed by the monks to the tenth or the eleventh century recommends this material in the manufacture of white lead. There is unfortunately some doubt respecting the date of this manuscript. Parts of it are probably as old as the twelfth century, but other portions are unquestionably of much more modern date. Eraclius, however, dating as early as the ninth or tenth century, recommends stable-litter as a ferment, and Saint Audemar, as early as the thirteenth or the fourteenth century, directs that stable-dung shall be used in making white lead. This author also says that grape-skins, or the refuse of the grapes after pressing, may be used as a ferment instead of stable-litter.[1] The use of stable-litter in the manufacture of white lead is also referred to in the "Marciana," and in other ancient manuscripts. It is clear, then, that the use of this material, and the process used by the Dutch, were known in Italy as early as the thirteenth century, and probably very much earlier. It is impossible,

[1] MSS. of Petrus de Sancto Audemaro, in Mrs. Merrifield's Original Treatises, etc.

therefore, that the Dutch invented a process which is clearly described in manuscripts written before the foundation of Amsterdam, and it is unlikely that they borrowed from the Arabs in Spain a method which had been practised for more than three hundred years in the Italian cities with which their neighbors, the Flemings, had been in constant communication. Two centuries before the period when the Dutch are said to have borrowed the art of manufacturing white lead from the Saracens, Italy was the recognized centre of art, and artists from other countries made frequent journeys thither for study and practice. Examples of the work of Van Eyck, the great Flemish painter, were exhibited in Italy as early as 1410, and Antonello da Messina and other Italian artists visited Flanders and studied with him.[1] Intercourse was frequent and easy between the artists of the two countries, and the *secretii* of the Italians were unquestionably well known to the Flemish painters, and especially the method of preparing so important a pigment as white lead was, even at that early day.

The encouragement given in Italy to art during the later centuries of the middle ages resulted in the production of the works of a long line of illustrious artists, which have been the crowning glory of that favored land. It is said that many buildings in Venice were elaborately frescoed and decorated on the outside by Titian, Giorgione, Paul Veronese, Tintoretto, and other great masters.[2]

This enthusiasm for the art of painting, and the resulting increase in the demand for materials led to the preparation and the sale of pigments by others than the monks, and many early manuscripts refer to the apothecaries and dealers who furnished supplies. There can be no doubt,

[1] Eastlake, History of Oil Painting, vol. i. p. 192.

[2] C. L. Eastlake, Contributions to the Literature of the Fine Arts (London, 1848), p. 173.

therefore, that in the fourteenth and fifteenth centuries, and probably much earlier, the preparation and sale of pigments, which was a well-established pursuit in the days of the empire, had been revived, and had become in Italy a thoroughly recognized industry; and that the friars, though they still continued to supply, perhaps through the apothecaries and other dealers, a portion of the demand for such substances, no longer monopolized the business.

The Italians at this early period not only practised the art of painting in their own country, but carried it to other countries of Europe. In 1260, by a precept to the sheriff of Surrey, Henry III. ordered that the paintings of the great hall at Guilford be repaired, and that there be painted "on the white wall at the head of our bed a certain cloth or pall, etc., as we have directed *William of Florence, painter*."[1] In the reign of Edward I., 1274, an order was issued to pay William, the painter, 36*s*. for the painting of twelve mews; and to Stephen Ferran 2*s*. for twenty pounds of white; and in the same year, to Reymund, 2*s*. 10*d*. for seventeen pounds of white lead, and 16*s*. for sixteen gallons of oil. In 1289, among other materials purchased to repair the Painted Chamber, we find white lead, red lead, vermilion, oil, etc.[2] It will thus be seen that three hundred years before the Dutch are said to have originated, or to have borrowed from the Saracens in Spain, a process for making white lead the pigment was in common use in England, and that one of the principal artists or workmen was an Italian. Matthioli, writing in 1540, says: "The Venetian ceruse is the best, but it is also made in several other cities of Italy."[3] This indicates that the industry had been established in that country for many years. There can

[1] Walpole, Anecdotes of Painting, vol. i. p. 14.
[2] Eastlake, History of Oil Painting, vol. i. pp. 52, 53, 109.
[3] Matthioli, Commentarii Dioscoridis, etc., p. 667.

scarcely be a question, therefore, of the priority of the Italians in the manufacture of white lead, and there is certainly no doubt concerning the enviable reputation of the Venetian products for many centuries. English and other authors of the sixteenth century mention Venetian white lead and no other, as if the Italians were the only manufacturers in Europe. An old black-letter treatise on the "Art of Limming," printed in 1581, and preserved in the British Museum, refers only to "Vennis cereuse."[1]

It is probably true that the manufacture of white lead was introduced into Holland in the sixteenth century, as writers of the following century refer to the products of the Dutch factories. The Dutch, however, seem to have been led by their greed and their desire to drive the productions of the Venetians from the markets of Europe, to adopt a system of falsification, which probably retarded rather than advanced the object they had in view. The Italian manufacturers, on the contrary, used great care in the preparation of their pigments, and preserved the purity and the excellence of their products notwithstanding the unfair competition created by the sophistications resorted to by their Dutch and English rivals; for the English who began the manufacture in the early part of the seventeenth century soon surpassed the Dutch in the adulteration of their products. The Venetians retained their hold upon the trade for very many years, and their white lead was long esteemed the best, even in the markets of Holland and of England.

M. Pomet, chief druggist to King Louis XIV., says that the true ceruse is "that which we call Venetian, because *the Venetians were the first who made it.*" He complains of its great cost, and says that they used in France but

[1] A Very Proper Treatise, wherein is breefely sett forth the Arte of Limming, etc., London, 1581.

little else than the *ceruse de Holland*, which was cheaper, and was as much esteemed by the painter; "but in this they were wrong, as the Dutch ceruse had so much chalk in it that it was of no long duration, whereas the Venetian ceruse was pure." [1] In Zedler's Lexicon, edition of 1733, it is said that the Venetians were quite the first to make white lead, and that it was the best, but more expensive than the Dutch and English. The painters bought the Holland ceruse because it was cheaper, "but the *ceruse de Holland* contained much chalk, whereas the Venetian was pure, of great enduring qualities, and kept white until the last. Bad as the Holland white lead is," this author continues, "the English is much worse, as it contains a greater amount of adulterant." [2] Boerhaave says Venice white lead is the best, and should alone be used by apothecaries.[3] The industry had been greatly extended in the time of Von Justi, who says, writing in 1758: "White lead is in much greater demand than one would suppose; the manufacture is not enough to supply the demand in this Prussian kingdom. It is best not to falsify white lead, but to prepare it pure. In Holland and England we find that a good proportion of chalk is added, and so," he quaintly remarks, "we have been obliged to do this that we may sell it at the same price. Only the Venetian," he continues, "is wholly pure, and on that account it is much sought after, and is sold at a higher price." [4]

Watin remarks that the best white lead formerly came from Venice, but the English and Dutch now make it. He also states that a very fine and white ceruse came from Rome, but it was very dear. *Ceruse de Krems* was

[1] Pomet, A Compleat History of Druggs, p. 125.

[2] Zedler's Lexicon (edition 1733), article Bleiweiss.

[3] Boerhaave, Elements of Chemistry.

[4] Johann Heinrich Gottlob Von Justi, Vollständige Abhandlung von denen Manufacturen und Fabriken (Koppenhagen, 1758), p. 518.

also in much favor, "made at a little town in the Basse Autriche." It was better than that of domestic manufacture, but dearer.[1]

The encyclopædias of this period generally refer to the universal sophistication of the Dutch and English white leads. In Krünitz it is stated that the custom of adulterating white lead prevailed in the Dutch and English factories, and that the only kind to be obtained in a perfectly pure state was the Venetian, which on that account commanded a higher price.[2] An English Cyclopædia (Howard's) contributes further testimony, by stating that Venetian white lead ought always to be used by the apothecary, on account of its purity;[3] and in Chambers's (ed. of 1786) it is stated that the best ceruse is that of Venice, but it is rarely used, the English and Dutch being mostly sold, though they were largely adulterated with chalk, — the Dutch being rather the better in this respect.[4] Leuchs remarks that the trade in white lead formerly belonged to Italy, but that the *ceruse de Holland* was the most renowned after the Venetian, but that now (1829), the English surpassed it.[5] Lefort says that the manufacture of ceruse passed successively to Venice, Krems, Holland, England, and to France.[6] According to Maigne, after the fall of Rome the preparation of white lead was monopolized by the Arabs, then factories were established at Venice, then in Holland, and afterwards in England.[7]

The earliest notice found of the methods employed by the Venetians is in a work published in London in 1676.

[1] L'Art du Peintre, etc., par Le Sieur J. F. Watin (Liége, 1774), pp. 17, 18.

[2] Œconomische Encyklopedie Krünitz (1787).

[3] Howard's New Royal Cyclopædia, 1788, article White Lead.

[4] Chambers's Cyclopædia, 1786, article White Lead.

[5] J. Ch. Leuchs, Traité Complet des Propriétés de la Préparation et de l'Emploi des Matières Tinctorales et de la Couleurs (Paris, 1829), p. 7.

[6] M. J. Lefort, Chimie des Couleurs.

[7] Maigne, Universal Dictionary, p. 79.

The author mentions only Venice ceruse, and describes its manufacture as follows: "Sheet lead is cut in long and narrow strips, rolled in a spiral, and placed in earthen pots with sharp vinegar; the lead must not touch the vinegar. Cover it close, and leave for some time. The corrosive fumes of the vinegar reduce the *superficies* of the lead to a white calx, which they separate by knocking upon it with a hammer. There are two kinds of this sold at the color shops, — one called ceruse, which is most pure, the other called white lead."[1] In a later edition the author refers to an account of the methods employed by the Venetians, described by Sir Philiberto Vernatti in 1678. Vernatti says: "First, pigs of clean and soft lead are cast into thin plates, a yard long, six inches wide, and to the thickness of the back of a knife. These are rolled with some art round, but so as the surfaces nowhere meet to touch, for where they do no ceruse grows. Thus rolled they are put each in a pot just capable to hold one, upheld by a little bar from the bottom, that it come not to touch the vinegar, which is put into each pot to effect the corrosion. Next, a square bed is made of new horse-dung, so big as to hold twenty pots abreast, and to make up the number four hundred in one bed. Then each pot is covered with a plate of lead, and lastly all with boards, as close as conveniently can be. This repeated four times makes one 'heap,' so called, containing sixteen hundred pots. After three weeks the pots are taken up, the plates unrolled, laid upon a board, and beaten with 'battledores,' till all the flakes come off, which, if good, prove thick, hard, and weighty; if otherwise, fuzzy and light, or sometimes black and burned, if the dung prove not well ordered; and sometimes there will be none. From the beating-table the flakes are carried to the mill, and with water ground between mill-stones until they be brought to an almost

[1] John Smith, The Art of Painting in Oyl, London, 1676.

impalpable fineness; after which it is moulded into small parcels and exposed to the sun to dry until it be hard, and so fit for use."

"The accidents to the work are: that two pots alike ordered, and set one by the other, without any possible distinction of advantage, shall yield, the one thick and good flakes, the other few and small, or none, which happeneth in greater quantities, even over whole beds sometimes. Sometimes the pots are taken up all dry, and so sometimes prove best; sometimes again they are taken up wet. Whether this arises from the vapors coming from below, or the moisture that is squeezed out by the weight of the pots, we cannot discover. This we observe, that the plates which cover the pots yield better and thicker flakes than do the rolls within; and the outsides, next the planks, bigger and better than the insides, next the rolls and the spirits that first arise out of the vinegar. We therefore question much whether the strongest-bodied vinegar, or the quickest and sharpest be the most effectual." [1]

This author writes upon this subject like an expert, and those who have had experience in the manufacture of white lead will readily agree that his description is clear and accurate, and that his comments are intelligent and judicious.

This method, so carefully described by Vernatti, was the process employed in Venice in the seventeenth century. It corresponds in every particular to the method now known as the Dutch process, and is simply the enlargement, incident to the increased demand for the product, of the methods described by Theophilus, and other authors of early manuscripts, of undoubted Italian origin; and

[1] Sir Philiberto Vernatti, Philosophical Transactions (London, Jan.–Feb., 1678), "A Relation of the Making of Ceruse." Wine lees and bits of marble were added to the vinegar.

there can hardly be a question that the process was in use in Italy many centuries before the date of Vernatti's description.

It is extremely improbable that the Italians borrowed their methods in the sixteenth or seventeenth century from the Dutch; besides, Muspratt tells us that the process originally used by the latter consisted in first casting the metal in thin sheets, then bending them in the middle to allow them to be hung over a strip of wood which was to serve as a support. Wooden boxes were provided, five feet long, twelve inches broad, and ten inches deep; a number of strips of wood were arranged in each box, so that a sheet of lead could be hung upon each in such a manner as to prevent the sheets from touching one another, or the sides or the bottom of the box. A mixture of vinegar and wine lees was then introduced into each box and the covers fixed securely on. When a number of these boxes were so prepared, they were placed in a close room, heated to a temperature of 80° or 90° Fahrenheit, and allowed to remain fifteen days, the temperature being kept to about the same point during this period. The heat volatilized the acetic acid, and by the decomposition of the wine lees carbon dioxide was evolved, the atmosphere was saturated with moisture, and the conditions consonant with the theory of the production of white lead by the Dutch process were all present. The heat of the room was sometimes maintained by the decomposition of stable-manure placed therein.[1]

This description closely resembles the method adopted in Germany in modern times, in place of the so-called Dutch method, formerly in use in German factories. If Muspratt's statement is correct, and this was the original method in use by the Dutch manufacturers, they must

[1] Dr. Sheridan Muspratt, Chemistry Applied to the Arts, etc., 2 vols., vol. ii, p. 478.

have changed their practice before the middle of the last century, as Gabriel Jars, an astute and every way trustworthy scientific traveller and writer, describes fully and intelligently the methods employed by the Dutch at that period. Writing in 1760–65, Jars says: "The manufacture of ceruse and *blanc de plomb,* of minium, salts of Saturn (lead acetate) and other chemical products are monopolized by England and Holland." The secret methods of the Dutch manufacturers were closely guarded, and entrance to their factories was stoutly denied, but Jars finally succeeded in gaining admission to establishments in Rotterdam and in Amsterdam. At this time a difference was recognized between ceruse and *blanc de plomb;* the former was a mixture of white lead with chalk, or other adulterants, and the latter was understood to be absolutely pure white lead. It was also known under the name of "flake-white." The Dutch used English pig-lead for the manufacture of white lead, receiving it in pigs of about one hundred and fifty pounds' weight. The methods employed are described with much minuteness by Jars, who was a most careful and intelligent observer.

The lead was first cast in thin sheets, which were rolled in a spiral, and placed in earthen pots, seven to eight inches high and four to five inches in diameter, made wider at the top than at the bottom. To prevent the lead from falling to the bottom, they placed inside the pot, and at about one third of its depth, a piece of wood, cut the length of the diameter of the pot. This was the Rotterdam method. At Amsterdam the manufacturers had moulded in the inside of the pot, and at about one third its height, three little points which served, instead of the wood, to support the lead. The stacks were built in one range of four, each being fifteen feet square. After the pots had been filled up to an indicated point with vinegar, and the spiral of lead placed in position in each

pot, they were arranged in rows in the stack upon a bed of dung, four feet thick; the pots were placed together as closely as possible, and when the bed was covered with the pots, plates of lead were laid upon them, and the whole layer covered with boards. These boards were then covered with dung, and another tier of pots placed as before, filled with vinegar and lead, and covered in the same manner. This was repeated until five tiers, or layers, were built up. The lead was left in the stacks from four to five weeks, "according," Jars says, "to the season, and the quality of the dung." In one of the layers which Jars saw opened, he remarked that the action did not appear to be equally satisfactory. In some the sheets of lead were entirely corroded, in others the operation was partial only, while in a few the surface of the sheets was only slightly attacked. This unequal action he attributed to the dung heating more in some parts than in others. The sheets covering the pots formed a crust or scale, harder and more compact, and were put to one side to be used in the manufacture of *blanc de plomb.* When the dung had been used several times it was replaced by new; that rejected was sold to be used as a fertilizer. The sheets which were partially converted were taken from the pots, and placed upon heavy tables, and beaten with mallets to separate the white lead from the unconverted lead, care being taken to sprinkle it with water from time to time, to abate the dust. The ceruse was now removed to the mills, where, in Amsterdam, it was twice, and in Rotterdam, three times ground in water, the mills being placed one above another, the lead falling from the upper mill directly to the one below it, finally passing to a tub placed below to receive it.

The workmen having in charge the grinding of the lead, fed the ceruse from the tubs with a ladle into the eye of the stone, adding, from time to time, chalk in desired proportions to form the mixture. This mixture

formed the ceruse. The *blanc de plomb*, which was pure white lead, was ground without the admixture of any substance, "and being," Jars says, "harder, and requiring to be finer, and ground with more care, the mills could produce but ten quintals per day, while of the ceruse, fifteen quintals were turned out."

The last operation, drying, was managed as follows: the ceruse, in a pulpy state, was filled into unglazed earthen pots, in shape like a section of an inverted cone; these pots were placed upon long wooden shelves, in a long and narrow building, in the sides of which a great number of little doors were provided, to open and close at pleasure, to shield the ceruse from the sun and rain, which would impair its color. After five or six weeks the pots were removed, and the ceruse was turned out, the contents of each pot forming a conical mass, or loaf; when perfectly dry this was trimmed, tied up in blue paper, and packed in barrels for market.

The *blanc de plomb* was treated in the same manner, except that the loaves were smaller, and were called "*blanc de plomb d'écailles*."[1] Sometimes this term, "flake-white," included pieces of perfectly corroded white lead, as it came from the beds, without grinding or preparation. Artists are frequently advised, in the literature of the period, to buy only this substance, and to grind and prepare it themselves, to insure absolute purity.

This extract from Jars shows that the Dutch, in the middle of the eighteenth century, made white lead by the process in use by the Venetians a hundred years earlier, who in turn merely enlarged the process described by the authors of manuscripts of the tenth to the twelfth century. The process originally in practice in Germany was the same as described by Vernatti as in use in Venice, and which may properly be termed the "Italian method." The

[1] Gabriel Jars, Voyages Metallurgiques (Paris, 1780), vol. ii. sec. 8.

Germans, however, have very generally changed their methods to what is known as the "chamber process." This is a modification of the Dutch method, and is almost precisely like that described by Muspratt as originally used by the Dutch manufacturers. Some changes in the details may be observed, but all the important features are present.

Tingry, describing the Dutch method, says that the pots containing the lead and vinegar are placed upon a warm sand bath, "but some manufacturers bury them in beds of dung. Other manufacturers," he continues, "so arrange their apparatus as to favor distillation; and when the vapors of vinegar condense and fall back into the vessel they are charged with lead, and are utilized in the manufacture of *sel de Saturn*, lead acetate." The white lead which was sold in scales, he asserts, was pure, but all that sold in a powdered state was adulterated.[1] This description recalls the methods described by ancient writers, where lead acetate and white lead were perhaps produced in the same apparatus.

United States Consul Eckstein, of Amsterdam, says in his report of December, 1886, to the State Department, that beyond doubt the numerous factories engaged in the manufacture of white lead in Holland, a century or more ago, employed the method known as the Dutch process; and that decomposing stable-litter was used as the source of heat. An attempt was made, "a good while ago," to introduce what is known as the German method at Wormerveer, and more recently at Utrecht, but it was abandoned. The precipitation method, according to this authority, has never been tried in Holland.[2]

After the discovery of the passage to India by the way

[1] P. F. Tingry, Traité Theoretique et Pratique sur l'Art de Faire et d'Appliquer les Vernis, etc. (Genève, 1803, 2 vols.), vol. ii. p. 16.

[2] Consular Report, No. 73 (Washington, 1886), p. 61.

of the Cape of Good Hope, and the consequent rupture of the trade with the East, which the Italian cities had held for so many centuries, the trade of the Dutch increased largely and rapidly. This enterprising people, favored by the wars which devastated France, added largely to their manufactures, and were enabled to compete successfully with the Italians, and finally to secure almost a monopoly of the trade in drugs, and materials used in painting. They established manufactories for the production of white lead at Amsterdam, Rotterdam, Dortrecht, and other cities, and supplying themselves with raw material from England, Germany, Sweden, France, and Spain, returned to those countries the manufactured products. For many years they retained this supremacy in the trade, until the German and English manufacturers, encouraged by the adoption of a wise policy by their governments, and favored by an abundant supply of raw material, were enabled to gradually usurp the place which the Dutch had held for so many years.[1]

The importance of the manufacture of white lead in Holland has declined very largely during the past fifty years. "Formerly," says Consul Eckstein, "there were a great many factories in Holland. Long rows of them were situated along the road from Amsterdam to Haarlem, and on the river Zann." In the year 1875, it is estimated that the ten factories then existing produced from 1,600 to 2,200 tons per annum. "At present," he says, "the product is much less, as several factories have been closed." There are factories now in operation at Rotterdam, Utrecht, Schoonhoven, Gonda, Kralingen, etc. Consul Visser, of Rotterdam, estimates the product of the white-lead factories in the Netherlands at four thousand tons per annum. This is chiefly consumed in the home markets, but little

[1] See Huet, View of the Dutch Trade; also Lexicon der Kaufmannischer (Wiesenschaften, 1838), article Blei.

being now exported. He states that some German and Belgian white lead is imported, and being of an inferior quality and cheaper, is used to mix with the Dutch when a second rate and cheaper variety is wanted.[1]

The manufacture of white lead has doubtless been continuously practised in Italy since the time of Vitruvius and Pliny. During the period between the fall of the Empire and the Revival, the extremely limited demand was supplied from the laboratories of the monastic establishments; but after the Revival, the manufacture of white lead became a well established industry in the secular world, and has so continued to the present day. The enterprise of the Dutch and of the English has deprived the Italian manufacturers of their monopoly of the trade of Northern Europe; but they continue to supply Italy, and retain the trade of the Levant. Until the vigorous working of the Sardinian lead mines, encouraged some twenty-five years ago by the wise measures of Victor Emanuel II., the Italian manufacturers were at some disadvantage, being forced to bring from Spain and other foreign countries their supplies of raw material; but in later years they have drawn their metallic lead from their own mines, and have been enabled to substantially increase their output of white lead.

According to Mr. Consul Johnson, in a report of trades and industries of the city of Venice presented in 1773 to the *Deputazione Straordinaria Delle Arte*, the manufacture of white lead is not mentioned. Two establishments, he says, formerly existed in Venice, but both had ceased operations before 1830. The method used at these factories was probably that commonly known as the Dutch process. In 1840 a factory was established in which a process similar to that in use at Klagenfurth was employed; but

[1] Consular Report, No. 74 (Washington, 1887): Report of John Visser, Esq., Consul, p. 499.

the competition of the Carinthian manufacturers soon caused the abandonment of the enterprise.[1]

In the last century there were factories at Venice, Genoa, Coregliano, and at Rome; but the principal production of white lead in Italy, at the present day, is at Genoa and its neighborhood. At Cogoleto, fourteen miles from Genoa, the principal seat of the industry, there are said to be fifteen manufactories, eight of which are now in operation, producing annually about twenty-five hundred tons. There are eight small establishments at Naples, and one at Milan. Consul-General Alden, in his report to the State Department, does not refer to a factory in Rome. The manufacture there is perhaps abandoned.

The method universally employed in Italy, until very recent times, was the Dutch process. In 1881 a modification of this method, closely resembling that adopted by the German manufacturers, was introduced at Cogoleto. This process is described as follows: "The lead is cast in thin sheets, which are hung in a close chamber; on the floor a number of copper receptacles are placed, each being in communication, by pipes, with a boiler in which dilute acetic acid is volatilized, and with a furnace in which carbon dioxide is produced. These vapors are admitted into the chamber in proper quantities and proportions, and at the end of six weeks the conversion of the metallic lead is complete."

At Milan a process, described as transforming metallic lead into white lead "by the use of revolving heaters," is said to be in use. The annual production of white lead in Italy, in the early years of this century, is placed at 800 to 1,000 tons; in 1840, at 1,500 tons; and at the present time it is estimated that 3,500 to 4,000 tons are produced. White lead, ground in oil and prepared for the painter, is

[1] United States Consular Report, No. 78 (Washington, 1887): Report of Consul H. Abert Johnson, p. 445.

still known under the name of *biacca*, the term given to it by the monks of the middle ages; while in the dry state, in which condition it is usually sold, it is called *carbonato di piombo.*

The Italian manufacturers successfully resisted the temptation to adulterate their productions until 1862, and to that time maintained their deservedly high reputation. Since that date they have yielded to the universal practice in Europe of sophisticating white lead, and now compete with the English and German manufacturers in the production of adulterated wares.[1]

The manufacture of white lead was introduced into Belgium about the year 1815. Watin, in a work published at Liége in 1774, bewails the supineness of his countrymen, and refers to the enterprise of the Dutch, who bought the ore and vinegar produced in his district, and returned the manufactured *blanc de plomb.* This author describes the methods in use by the Dutch, but says the pots should be luted and put over a moderate fire, or warm cinders; but in this, perhaps, he refers to a laboratory experiment, or to the manufacture in a small way; as "in large establishments," he observes, "the practice was to bury the pots in beds of dung for ten days." At the expiration of that time the pots were opened, and the plates of lead were found thickened and covered with white pieces, hard and friable, and termed *blanc de plomb en écailles,* which was ground in water and dried.[2] This author describes a method of testing the purity of white lead, which is distinguished for its extreme simplicity, and its convincing results. This method has been extensively advertised by some manufacturers in the United States, and this has had much to do with the substitution of pure lead, by the best painters

[1] United States Consular Report, No. 75 (Washington, 1887): Report of Consul-General Alden, pp. 581, 582; Report of Consul Fletcher, p. 583.

[2] Le Sieur J. F. Watin, L'Art du Peintre, etc. (Liége, 1774), p. 17.

of this country, for the fraudulent mixtures imposed upon them by unscrupulous dealers twenty years ago. Watin recommends that a piece of charcoal be provided, in which a small cavity is bored; into this cavity a pinch of white lead is introduced, and by means of a flame mixed with air; if the sample is pure the carbonic acid is dissipated, and globules of metallic lead result. Impurities, even if present in small quantities, prevent the satisfactory termination of this experiment; chalk parts with its carbonic acid and remains a white powder; barium sulphate is unchanged.

The process employed in Belgium in the manufacture of white lead is the Dutch method, stable-litter being generally used as the source of heat. The industry flourished in Belgium in the early part of this century, the proximity to the lead deposits enabling the Belgian manufacturers to successfully compete with the Dutch for the trade of France, where the products of the Belgian factories found a ready market. The exhaustion of the Belgian lead mines, with the consequent increase in the value of metallic lead, which is now brought from Spain and Germany, added to the increase in the production of the German white-lead factories and the sharp competition of the German manufacturers, has in later years deprived Belgium of her foreign trade, and the manufacture has largely declined in importance.[1]

[1] See Report of Consul G. D. Robertson to State Department: Consular Report, No. 74 (Washington, 1887), p. 492.

CHAPTER XIII.

WHITE LEAD IN GREAT BRITAIN.

THE manufacture of white lead in a large way was introduced into England some years subsequent to the establishment of the industry in Holland. The policy of Elizabeth, in absolutely prohibiting the importation into England of all articles produced from metals, encouraged the establishment in her own dominions of manufacturing industries. Previous to her reign, Germany and other continental nations had drawn supplies of raw materials from Great Britain, and had returned the same substances transformed into articles of every-day use and necessity.

Red lead and litharge had doubtless been produced in England for many years, but probably only as incidental to the desilverizing of the product of the lead mines. During the reign of Elizabeth, encouraged by her prohibitory decrees, attempts were made to establish the manufacture of white lead upon a permanent basis. An English writer on painting and materials, in 1581,[1] refers to "Vennis cereuse," but makes no mention of any home production. Venice white lead was undoubtedly considered to be the best, and this may be a sufficient explanation of his omission; but it is extremely probable that the manufacture of white lead was not then thoroughly established in England. In 1622, however, one Christopher Eland was awarded a patent, No. 22, "for makinge of white and

[1] A Very Proper Treatise, etc., London, 1581.

redd leade as it is now made for painters within this our realme of Englande." No specifications of this patent are given, but by its terms Eland seems to have secured a monopoly of the trade in red lead in England. Eland's patent is entitled "for makinge of white and redd leade," etc.; no reference is made to white lead except in the above quotation, but it would appear from the provisions that there were four work-houses, or factories, in England for the manufacture of red lead; and as white lead is mentioned in connection with red lead, that pigment was doubtless also manufactured. In 1635, patent No. 88 was granted to James Rosse and Alexander Roberte, for "a newe way of makeing of redd and white leade, and glazing earthenware with lytharge out of which the silver is first extracted."[1] No specifications of this patent were enrolled, but it is evident that the manufacture of white lead was then completely established.

An English author, a little later, treating of pigments to be used in painting, says: "The first in order of whites, — the most excellent, pure, virgin colours, — are ceruse and white lead. The latter is the best for use and less subject to mixtures." "Ceruse" — and this name was applied at that time to adulterated white lead — "ceruse," he says, "after it is wrought will starve, lavish, and dye, and being laid on with a pencil a fair white, will in a few months become a russet, reddish, or yellowish." "White lead," — by which term flake-white, or pure lead as it came from the corroding-pot, was intended, — "if you grind it fine, as all our colours must be, it will glisten and shine both in the shell,[2] and after it is wrought; and if not ground it will not work, nor be serviceable. To prevent

[1] Abridgments of Specifications relating to Paints, Colours, and Varnishes (London, 1871), p. 2.

[2] Painter-artists in that day mixed their colors in a shell; the painter's palette is a comparatively modern invention.

these inconveniences of both colors," he continues, "this is the remedy: Before you grind either of them, lay them — especially the white lead — in the sun for two or three days, which will exhale and draw away the salt, grease, and commixtures, that starve and poison the colour; besides, you must scrape off the superficies of the white lead, reserving only the middle as the cleanest and purest. Be careful of your whites," he says, "that being the ground and foundation of all your other colours, and if faulty, all the work is marred." [1]

Nicolius le Febvre, "Royal Professor in Chymistry to His Majesty of England, and Apothecary to His Honourable Household," had a very mean opinion of the metal lead, and in his elaborate and ponderous work dismisses the subject we have under consideration in a very few words. He says: "White lead is made by suspending plates of lead upon a spirit or sharp liquid, the vapour of which does by degrees calcine the lead and reduces it to that substance called white lead, or ceruss." [2] Smith, in the first edition of "The Art of Painting in Oyl," says: "Ceruse is only white lead more refined, which advances its price and renders it something more esteemed among picture-drawers; but the white lead is every way as useful. It is the only white color used in painting in oyl." [3] In the second edition Smith says that white lead owes its origin to the common plumbers' lead, and he describes the process of manufacture as practised at Venice, following Vernatti, to whose description he refers. He says: "The principle of all whites is white lead, two kinds of which are sold at the colour shops, — one called ceruse, which is most pure, the other called white lead." In this,

[1] Wm. Sanderson, Esq., Graphice: The Use of the Pen and Pencil (London, 1658), p. 55.

[2] Nicolius le Febvre, A Compendious Body of Chymistry, vol. ii. p. 185.

[3] John Smith, The Art of Painting in Oyl, p. 11.

Smith is at variance with Sanderson, who says that white lead is most pure; but Smith adds, "another white is sold, called 'flake-white,' which by some is said to be the best. The reason I do not understand, except because it is scarce and dear. This lead is said to be found under the lead of some very old buildings, where time has, by the assistance of some sharp quality of the air, thus reduced the undermost superficies of the lead in thin white calx, which proves a very good white, but, in my opinion, not exceeding the best ceruse." After describing the manner of grinding colors in oil, he recommends, "if they are to be kept," that they be put up in bladders, to keep them from drying.[1] Smith defines the meaning of the term "body," as applied to pigments; and the possession of this property by white lead seems to have been well understood at that time. "Some may say," he observes, "what is to be understood by a colour's bearing body. I say, to bear a body is to be of such a nature as is capable of being ground so fine, and mixing with the oyl so intimately, as to seem only a thick oyl of the same colour; and of this nature is ceruse."[2]

On the 15th of December, 1749, patent No. 651 was issued to Sir James Creed, "for a method or way of making white lead," etc. An abridgment of the specifications is as follows: "Making white lead by the heat of fire, — instead of horse-dung, hitherto the common method, — placing in chambers, rooms, stoves, ovens, or other close and confined places heated with fire, lead cast in thin plates; and raising or conveying therein the steam or vapour of vinegar or other acid, raised by fire, until the plates are corroded thereby into flakes, or dust, of white lead; the steam or heat is to be regulated by slides, valves, stopples, stopcocks, or the like, and discharged into the air, or collected

[1] John Smith, The Art of Painting in Oyl (2d ed. 1678), p. 15.
[2] Ibid., p. 27.

in a still-head and condensed by a refrigerator." [1] This is the first patent granted in England for the manufacture of white lead, the specifications of which are preserved. The method here described is a modification of the Dutch process, and is based upon principles familiarly known in this country as the "chamber process." It resembles very closely what is now known in Europe as the "German method," — a process introduced very generally into that country during the present century. Improvements in the details of Sir James Creed's process have been repeatedly patented, and the manufacture of white lead by this method established in this country and in England during the past fifty years; but these enterprises have universally resulted disastrously.

Gabriel Jars extended his "Voyages Metallurgiques" to England, and visited the white-lead works at Sheffield. He mentions no other seat of the manufacture, and so acute an observer would probably select one of the most important establishments for his observations and inquiries. Jars found the methods in use at Sheffield (in 1760) much the same as those he observed at Rotterdam and at Amsterdam; the differences being unimportant, and consisting principally in the manner of casting the lead preparatory to placing it in the pots, and in the separation of the carbonate from the unconverted metallic lead upon its removal from the stacks. At Sheffield this was effected by agitating it in a closed box, provided with a grating. He also mentions some improvements in washing and drying. White lead was dried at that time without the use of artificial heat. Jars says that drying with artificial heat had a tendency to turn white lead yellow; so it was allowed to dry naturally, for which six weeks in winter, and four weeks in summer, was necessary. [2]

[1] Abridgments of Specifications, etc., p. 3.
[2] Jars, Voyages Metallurgiques, vol. ii. sec. 8.

Sir John Hill, in a note in his translation of Theophrastus's "History of Stones," says that at that time (1774) there were three or four different modes of making white lead in use in England, but "all were of the same nature as that described by Theophrastus, and are the effect of vinegar upon lead." By some, he says, it was made by "infusing filings of lead in strong vinegar, which in twelve or fourteen days would be almost entirely dissolved, and leave a very good ceruse at the bottom of the vessel." Others made it by plunging thin plates of the same metal into vinegar and placing the vessel over a gentle heat. In about ten days the plates would be found to be covered with a white "rust," which was scraped off; and the plates were again plunged into vinegar, scraped again after another interval, and the operation repeated until the plates "were wholly eaten in pieces." The scrapings were afterwards ground together. Another method he describes as putting vinegar into an earthen vessel, covering the vessel with a plate of lead, and placing it in the sun in hot weather. After ten days, he says, the lead would be dissolved, and precipitated in the form of ceruse to the bottom of the vessel.[1]

These processes are so very similar to those described by Theophrastus, Vitruvius, Pliny, and Dioscorides, and so unlike the methods in use at Sheffield fourteen years earlier, as described by Jars, that we may infer that the learned translator of the old Greek writer was unacquainted with the practice in his own country, and that he was content to assume that the old methods were still in vogue.

There has been lately introduced into the markets of England and of the United States, as a substitute for white lead, the purified and decolorized condensation of the lead fumes resulting from the smelting of galena.

[1] Theophrastus, History of Stones, p. 223, note.

The ancients recovered zinc oxide from the chimneys of their smelting-furnaces, and employed it as a remedial agent; and Agricola illustrates and describes, with much minuteness, the construction of chambers for the condensation and collection of metallic vapors.[1] Bishop Watson, in his "Chemical Essays," written about 1780, describes the horizontal chimney, some two or three hundred yards long, for the condensation and collection of lead fumes, which is much better for this purpose than the chamber described by Agricola. Watson experienced a strange opposition on the part of the Derbyshire smelters, when he tried to persuade them to adopt this device to save the lead which was lost by volatilization and escaped to the outer air; but the principle was demonstrated, and the prejudice of the smelters overcome, in an accidental manner. A horizontal chimney of this description was built at Middleton Dale, to prevent injury to a pasture by the smoke and fumes of a furnace, and was found to correct the evil, and also to collect large quantities of the lead fumes volatilized by the heat of the furnace, which had condensed in the chimney. This sublimed lead was whitish in appearance, and soon became an article of commerce, being sold to the painters, who paid £10 to £12 per ton for it.[2] Modifications of Watson's chimney have been generally adopted in modern smelting-works. Watson describes the usual method of preparing white lead in England in his time (1775–1780) as the Dutch process. The lead was cast in thin plates, rolled in spirals, and placed in earthen pots which were buried in beds of stable-litter. After some weeks, the spirals were found covered with white scales, which were beaten off, washed, and ground in a mill, and the product, he says, "constitutes the white lead of the shops, except that generally, even

[1] Agricola, De Re Metallica, p. 323.
[2] Watson, Chemical Essays, vol. iii. p. 284.

before it gets into the hands of the painter, it is adulterated with chalk." Watson adds the statement that "ceruse was formerly made by the vapour of putrid urine instead of vinegar."[1] Saint Audemar (1300 ?) recommends, in the manufacture of green, that wine, beer, or stale urine — which is better than fresh — be put in a wooden or earthen vase, in which strips of copper or brass are placed, and so arranged that the copper or brass does not touch the urine; the vase is then buried in horse-dung, and in the course of eight or nine days the green color is found adhering to the copper or brass.[2]

In the latter part of the eighteenth century, the manufacture of white lead must have assumed considerable importance in Great Britain, as several patents were granted for improvements in the old process, and for its manufacture by new methods. In 1781, James Turner patented a process by which red lead or litharge was mixed with half its weight of sea-salt, or "of sea-salt dissolved in water;" after triturating the mixture for twenty-four hours, the litharge, it was claimed, would be changed to a good white.

In the manufacture of white lead by the Dutch process, stable-litter was universally used as the source of heat and of carbon dioxide until 1787, when the use of spent tan-bark is mentioned. Richard Fishwick obtained a patent in that year for the use of spent tan-bark instead of stable-litter. The patentee claimed that the bark communicated a more certain and equal degree of heat to the vinegar and the lead.[3]

The Earl of Dundonald introduced a new method of making white lead in 1797. Metallic lead is to be brought to a "state of calx or oxyd; the calx is to be mixed with muriat of potash or *sal digestivus silvii* or with oxygenated

[1] Watson, Chemical Essays, vol. iii. p. 361.

[2] MSS. of Petrus de Sancto Audemaro: Original Treatises, etc., vol. i. p. 118.

[3] Abridgments of Specifications, etc., p. 12.

muriat of potash," in certain proportions, well mixed and stirred at intervals, and "alternately wetted with water (either impregnated or not with fixable air or carbonic acid) and dried by air or air in which carbonic acid is combined; the result is carbonat of lead and muriat of potash," the product was then washed for the elimination of the potash and the white lead ground, levigated, and dried. "Muriat of soda, or sea-salt," it was claimed, could be substituted for the potash salt, producing the same result. Turner, in 1781, obtained a patent for this method, and in 1799 John Wilkinson was granted letters-patent for the "discovery of a new method of making white lead," which is described as "grinding litharge very fine in sea-water or other saline mixture."[1] Notwithstanding the complete establishment of the manufacture of white lead in Great Britain at this time, and the activity displayed in the attempt to improve the methods of preparing it, the reputation of the home products was such that writers of the period warn the public against the villainous adulterations practised by the dealers. The Venetian was on all sides recommended as the best, and the only white lead which could be produced free from debasement. The Dutch productions, bad as they were, had a better reputation than the English.

The first decade of the present century was fruitful in the invention of new processes in the manufacture of white lead. In 1800, Thomas Grace proposed the use of spent hops or spent rapes or raisins, instead of the usual bed of horse-litter or spent tan-bark, in corroding lead. He also suggested a new method of preparing the vinegar or acid to be used; he substituted for "common water" the sour water in which grain has been steeped in making starch, or the wash after the distillation of spirit, sometimes also adding "the water which comes over with the oil of tur-

[1] Abridgments of Specifications, etc., p. 18.

pentine, when distilling the same." He dissolved in this liquid molasses, syrup, or sugar in certain proportions and fermented them in the usual manner.[1] His recommendation of the use of spent rapes or raisins, for which he received a patent, had been anticipated, as Saint Audemar suggested, more than four hundred years earlier, the use of "spent grapes" for a similar purpose.[2] Grace was necessarily ignorant of the suggestion of Saint Audemar, as at the date of his patent the manuscript of the French monk was hidden in the collection of Le Begue, at Paris, and locked in the Latin and the chirography of the middle ages. Saxellye obtained a patent, in 1804, for a process in which the pots containing the lead and acid were placed in a chamber, "heated by the combustion of fuel," and without the aid of horse-litter or tanners' bark. We are not informed of the manner of producing carbon dioxide.[3] In 1806, James Keir patented a process for treating chloride of lead with some alkaline substance containing carbonic acid. Noble, in 1808, passed a current of mixed carbonic acid and air through a vessel containing lead and a solution of acetate of lead;[4] and the next year, John Brierly was granted letters-patent for a process of "setting blue lead for the purpose of corroding the same into white lead." Brierly's method consisted in setting pots containing acid only upon the bed of tan-bark or horse-litter, covering them with boards having holes bored through them corresponding to the mouths of the pots underneath. The lead, cast in sheets, was rolled and placed directly upon the boards and immediately over the holes, so that the vapors arising from the decomposing bark or litter, and the evaporating acid, could readily attack them. Boards were placed edgewise as a support for another layer of boards which were

[1] Abridgments of Specifications, etc., p. 19.
[2] Mrs. Merrifield, Original Treatises, etc., p. 120.
[3] Abridgments of Specifications, etc., p. 20. [4] Ibid., p. 26.

covered with tan-bark, or litter, and pots, thus repeating the arrangement of the tier below.[1]

In 1818, George Fred Hagner took out a patent for granulating lead, by introducing it while melted into a revolving cylinder with an opening at one end; pyroligneous acid was introduced and a current of carbonic acid gas passed through the lead.[2] In 1821, Sadler obtained a patent for a *new* and improved method of making "carbonate of lead, formerly denominated ceruse, but now commonly called white lead." Sadler introduced carbonic acid, in gas or in solution, into a vessel containing a solution of sub-acetate of lead. Agitation was employed until "the absorption of carbonic acid took place."[3] John Ham, in 1826, patented a process which consisted in making the chamber or stack water-tight, by forming the bottom and sides to the depth of twelve inches of brick laid in cement. The chamber was filled to the height of three or four feet from the bottom with spent tan-bark "or any other vegetable substance susceptible to a similar decomposition;" above, flat layers of sheet-lead were arranged alternately, supported by laths. The top was covered with tan-bark. Vinegar or acetic aid was introduced by a pipe to the depth of about nine inches. Steam was passed through a pipe coiled about the bottom of the chamber to preserve the heat of the acid at 170° Fahrenheit.[4] Peter Groves obtained in the same year a patent for making white lead by roasting galena, grinding, washing, and mixing it with nitrate of potash and introducing it into a closed retort or cylinder, where it was treated with sulphuric acid and steamed. In 1833 a method was suggested for an improvement in the manufacture of white lead which is described as follows: "Pieces of lead of the shape and size of duck-shot are placed in a vessel lined with lead, and

[1] Abridgments of Specifications, etc., p. 26.
[2] Ibid., p. 36.
[3] Ibid., p. 37.
[4] Ibid., p. 41.

barely covered with water. The vessel is rocked from side to side, and the pellets, rolling backwards and forwards, produce a fine powder of lead. The moist powder is passed through a fine sieve, exposed to atmospheric air for ten days in a shallow open vessel, with frequent agitation, until it assumes a beautiful white color. "White lead, the inventor claimed," is thus made without the use of vinegar or acetic acid, and without the aid of heat except for the purpose of drying it after it is made."[1]

Of the many patents for improvements in the manufacture of white lead granted in England in the early years of this century, but few have been noticed; it will thus be seen that this was a period of great activity and ingenuity in providing, or in the attempt to provide, a more rational and scientific method for preparing white lead than the so-called Dutch process. This activity has continued in an intermittent manner to the present day, but was perhaps most pronounced between the years 1836 and 1841. It would be tedious and profitless to examine many of these suggested methods, since few of them offer anything strikingly original, and still fewer have any economic or practical value. Gossage and Benson patented a process in 1836, which Riffault terms *an improved Kremnitz method.* This process consists in "exposing to the action of carbonic acid gas a mixture of oxide of lead with acetic acid or acetate of lead and water, in such proportions that the acetic acid would not be capable of dissolving more than one fourth part of the oxide of lead when assisted by water." The mixture was spread upon trays and stirred, being exposed at the same time to the action of carbon dioxide, lead oxide being added from time to time, and the mixture kept damp by the addition of water.[2] In describing this as an improvement upon the Kremnitz process, Riffault probably supposed the *kremserweiss* or

[1] Abridgments of Specifications, etc., p. 44. [2] Ibid. p. 47.

kremnitzerweiss of the German manufacturers originated at Kremnitz. The truth is, white lead has never been made, in economic quantities at least, at Kremnitz; and no factory for this branch of manufacture has ever been established there. The term *kremnitzerweiss* is a corruption of *kremserweiss,* a name given to the product of the factory at Krems, celebrated in the last century for the excellence of its productions, which were made by the Dutch process.

Another method for the manufacture of white lead is described substantially as follows: Metallic lead is granulated and is placed in a revolving drum, and moistened from time to time with a solution of lead acetate. The lead is worn into fine particles by attrition, and while the mass is being agitated, carbon dioxide is introduced, resulting in the production of white lead. One of the most novel and practical of the numerous methods proposed was patented by Pattinson in 1849. After taking out patents in 1840 and in 1841 for processes depending upon the reactions of carbonates of lime and of magnesia upon chloride of lead, he patented his process for the manufacture of oxichlorid of lead, which is described as "the manufacture of oxichlorid of lead, composed of one atom of oxide of lead, one atom of chloride of lead, with or without an atom of water, by the use of chloride of lead, and lime, soda, potash, ammonia or baryta; lime is preferred, and on mixing limewater and chloride of lead in solution, both in certain proportions, this substance instantly forms and subsides." In practice the lead ore, galena, "is ground with hydrochloric acid, and in thirty or forty hours the lead and associated metals in the ore are converted into chlorides; a portion, however, from seven to ten per cent, is either unacted upon, or converted into sulphates by the traces of sulphuric acid contained in the hydrochloric acid. The impurities are eliminated,

and the mass is then introduced into tubs furnished with agitators, and a stream of hot water is allowed to flow in, the chloride of lead is gradually dissolved and precipitation is effected by means of lime, a perfectly clear solution of which is allowed to unite in a stream with a stream of the solution of chloride of lead."

In the same year, 1849, a patent was issued for a chamber process very similar in its specifications to the patent granted to Sir James Creed just one hundred years before. Undaunted by the failure of every new process heretofore invented to obtain a foothold, except Pattinson's oxichloride, the investigations continued; and though the experimenters frequently grew faint and weary, yet they still pursued. In 1853 two patents were issued for the application of electric currents in the production of white lead,—followed in later years by other methods, depending upon the precipitation of carbonate of lead, by carbonates of soda or of ammonia, from solutions of soluble salts of lead; the treatment of the ores, sulphides, and carbonates by roasting, and after treatment with acetic and carbonic acids; desulphurizing ores, and placing the product in "tan beds in the usual way of making white lead," and introducing hot acetic acid through pipes into the bottom of the beds; "decomposing sulphate of lead by pearl ash;" reducing metallic lead to a spongy state, or to small particles, by dropping it in water, or by centrifugal force, and treating it with acetic and carbonic acid. A patent was issued in 1866 for the preparation of sublimed lead, from the chimneys of the smelters, by treating it with hydrochloric acid, and precipitating the solution of chloride of lead with sulphuric or carbonic acid.

The sublimed-lead process patented by Lewis and Bartlett in the United States has recently been introduced into Great Britain. Extensive plants for the production of this substitute for white lead have been erected at

Glasgow, and at Bristol, the latter city being within a hundred miles of the spot where Bishop Watson, more than a hundred years ago, found it an article of manufacture and sale to the painters.

This statement of methods proposed in England for the manufacture of substitutes for white lead prepared by the Dutch process could be largely extended, but enough have been cited, perhaps, to show the wide range taken by experimenters. Every resource of chemistry and ingenuity seems to have been exhausted in the effort to provide a more acceptable method for the production of white lead than that persistently held to by the principal manufacturers of England and of the United States. Of the hundreds of substitutes suggested and patented, but one or two have shown the least persistence in England, and the output of such as have survived is extremely insignificant.

These modern processes rarely give any greater control over the chemical reactions than is afforded by the Dutch method; the character of the product is more irregular, is generally much inferior in quality, and is not produced at a less cost. The only advantage which may be claimed is, that by some the time required for production is less, thus rendering it unnecessary to carry so large an amount of material in process of manufacture, but this gain is more than offset by the uniformity and superiority of the white lead made by the Dutch process. In the new methods the investment in plant is quite as large, and the manipulation after corrosion is generally much the same, as by the Dutch process. It may therefore, perhaps, be claimed that no method has as yet been devised that will produce white lead equal in quality to that made by the ancient process at the same cost; and it may also be said that no substitute for white lead has yet been found possessing all its good qualities. It stands to-day, notwithstanding its well known imperfections, unrivalled as a white pig-

ment for most purposes in painting, and as the best base for colored paints.

As stated above, the principal English manufacturers adhere to the Dutch process in the production of white lead. Their practice varies but little from that described by Jars as in use in Holland and in England in 1760. They use spent tan-bark as a source of heat and carbon dioxide. And the pots are made to hold the acetic acid only; the lead, cast in bars, or small slabs called "wickets," about twelve inches long, two and a half inches wide, and a half an inch thick, is placed in piles directly upon these pots. The covering of the layer of pots consists of stout plank, supported at intervals by short pieces of scantling, resting upon planks laid upon the bed of tan, instead of being laid directly upon the pots which contain the lead, as is the practice in this country Newcastle on Tyne is now the principal seat of the manufacture in England, but important establishments exist at London, Chester, Sheffield, Bristol, Glasgow, and at other cities in the United Kingdom. One of the principal manufacturers in Great Britain estimates the annual production at fifty thousand tons. This is distributed by British enterprise to nearly every quarter of the civilized world.

CHAPTER XIV.

WHITE LEAD IN FRANCE.

THE establishment of the manufacture of white lead in France is of comparatively recent date. The absence of deposits of lead ore comparable in extent and richness to the lead fields of Spain and Germany has made France dependent upon neighboring nations for supplies of raw material. Early in this century public attention was directed to this branch of manufacturing industry by the discoveries of an eminent French chemist, and late authorities agree in the statement that the manufacture of white lead was introduced into France early in the present century. This statement is not quite correct, as Gabriel Jars, whose observations are entirely trustworthy, refers to a small establishment in operation in 1767 at Grenoble.[1]

There is little to be gleaned relating to the development of the manufacture of white lead from the works of French authors of the seventeenth and eighteenth centuries, except to show the sources from which the French received their supplies, and the customs of the trade. Pomet describes the Dutch method of manufacture, presumably as it was practised in Holland in his time, in a sufficiently accurate manner, and much as it is described by Jars and others who wrote at a later period. After corrosion, Pomet says, it was ground in water and put into moulds, "and so made into little cakes, which they

[1] Jars, Voyages Metallurgiques, vol. ii.

dry and put into blue papers as we find them." Ceruse so prepared Pomet declares to be the "true calx of lead." He compares it with that in general use in France at that time, which was imported from Holland and England, and which consisted, he says, principally of common chalk. The custom prevailed in Holland, at that period, of selling pieces of thoroughly corroded lead, as it came from the beds or stacks, — selected for whiteness and hardness, — to painters and artists, who preferred it in this condition, and ground it themselves in water to insure absolute purity. This lead was called *schieferweiss, blanc d'écailles,* and *blanc de plomb.* The Venetians alone preserved the purity of white lead, and Pomet recommends the purchase of Venetian ceruse only, to avoid the necessity of grinding it, with the consequent exposure to disease, and perhaps, he suggests, to death itself. He says, "The Dutch grind only the dust of the lead, which comes from bruising and beating their spirals as they come from the stacks, and as this dust is not sufficient to supply the great demand for ceruse in France and in other European countries, they mix a sort of marl, or white chalk, with it." The English white lead, Pomet claimed, was inferior to the Dutch, because they mixed more chalk with it, and that of a darker color. Pomet describes the characteristics of ceruse, of approved quality, as follows: "It should be extremely white, dry, soft and friable, the least broken, or mixed with as little dust as possible; if it cracks in handling it has not been well dried." [1]

Savary, Inspector-General of manufactures at the Custom House at Paris, in his "Universal Dictionary" says: "They use in Paris, and throughout France, as well as in other foreign countries, hardly any other ceruse but that of England and Holland." He describes briefly the Dutch method, generally agreeing with authors of the same period

[1] M. Pomet, A Compleat History of Druggs, vol. ii. p. 353.

in the details. He also unites with other writers in condemning the production of England and of Holland, on account of the gross adulterations practised in both countries. "The English," he remarks, "mixed more chalk with their lead than the Dutch, and that of a much inferior quality." The Venetian ceruse was still considered to be much the best, but on account of its high cost it was but little used. The painters of his time used ceruse both as an oil and a water-color, "and it made a beautiful white." The ladies, according to this authority, still used ceruse as they did in Pliny's time, "to beautify their complexions." [1]

The French continued to draw their principal supplies of white lead from England and Holland until the beginning of this century. In the "History of Inventions," etc., during the year 1812, a description is given of a process of manufacturing white lead invented by Montgolfier. By this process lead is cut into thin plates, by passing it over sharp knives or points; these plates are then suspended in a large rectangular box, in such a manner as to allow free circulation of air; a suitable furnace is prepared, the chimney of which, placed upon the dome of the furnace, after attaining an elevation of ten or fifteen feet, is made to take a horizontal direction, leading into a cask, in the lower part of which a quantity of vinegar is placed; this cask is connected with the rectangular box by a flue. The furnace, being charged with charcoal is fired and the gaseous products of combustion, passing through the chimney and into the cask, heat the vinegar; the vapors of acetic acid thus produced mix with the carbon dioxide resulting from the combustion of the charcoal, and pass into the rectangular box in which the plates of lead are suspended. The conditions necessary for the production of white lead are thus supplied.[2] M. Chaillot de Prusse, of Paris,

[1] Savary, Universal Dictionary, translated by M. Postlethwayt, London, 1751.

[2] Histoire des Inventions, etc., dans 1812 (Paris, 1814), vol. v. p. 200.

proposed dryers or heaters to provide the necessary heat in the corrosion of lead. The heaters, in the form of tunnels or flues, were built of brick, six feet long, and twelve inches high; several of these flues were built upon the floor of a room, and all were heated by means of a stove placed in the middle. Upon the top of these flues a brick base and side walls were erected for the reception of stone pots, which were provided with gratings of the same material placed in them at about two thirds their depth. Boiling vinegar, in which small quantities of *blue vitriol* had been dissolved, was poured into the pot, "care being taken that the vinegar should not rise in the pot so as to touch the lead." After the lead had been filled into the pots they were covered, sealed, and placed in the receptacle prepared for them on top of the flues or heat-conductors, with six inches of tan-bark underneath and ten inches above, "in order that the heat may be concentrated." The room was kept at a temperature of 20° C., and a month was required to complete the reaction. This inventor gives elaborate instructions respecting the preparation of the chalk with which the ceruse should be adulterated.[1]

Early in this century works were established at Clichy, near Paris, for the manufacture of white lead by the process of Thénard. By this method litharge is dissolved in acetic acid, producing a solution of basic acetate of lead, through which a current of carbon dioxide is passed; the reaction gives a precipitate of carbonate of lead and a solution of neutral acetate; litharge is now added to the solution, and subacetate of lead again obtained, which is treated as the first, and thus the operation is made, in a way, continuous. This measure is entirely rational and completely under control. The product is very fine and white, but it is much inferior in opacity to the white lead made by the Dutch process. It has been used in France for many years,

[1] Histoire des Inventions, etc., 1812.

and to a small extent, some years ago, it was distributed to other countries of Europe. The works at Clichy had attained considerable proportions as early as 1809, when exhaustive experiments were made at Paris to prove the great superiority of lead made by this process over the *ceruse de Hollande.*[1] Writers of the early part of this century are unanimous in their statements of the prevalence of the custom of adulterating white lead, and nearly all condemn it. The confusion respecting the name given to the purer and better variety is exasperating. In the seventeenth and eighteenth centuries authors recommend the white lead of the Venetians as the purest and best, but in the early part of the present century that product disappeared from the markets of the European countries north of the Alps. The enterprise of the Dutch and of the English, their proximity to the sources of supply of raw material, together with their unscrupulous use of adulterants, enabled them to undersell the Venetians and to undermine their trade. Some authors of the period under consideration declare that the only pure white lead sold was the *schieferweiss, blanc de plomb en écailles,* — pieces of corroded lead as it came from the beds, or stacks, and without any grinding or washing.

According to Merimée, white lead was the only white used in painting. It was made, he says, by different methods, resulting in products of diverse quality, known in commerce under the names, *ceruse, blanc de plomb, blanc en écailles, blanc de Krems,* and *blanc d'argent.* Ceruse, and particularly *ceruse de Hollande,* he tells us, was for a long time reputed to be the best; but "it was of a dirty white color and used principally to paint buildings." *Ceruse* was frequently mixed with chalk, and *ceruse d'Allemagne* contained a large proportion of sulphate of barytes, but

[1] See Libraire Classique, Larousse et Boyer (Paris, 1867), vol. iii. p. 790; also Archives des Decouverts et des Inventions (Paris, 1824), vol. vi. p. 240.

the *ceruse de Hollande* of the first quality was without any admixture. Flake-white was whiter than common ceruse, and could be made as white as Krems white if care was used in its preparation. It was not falsified in any degree, and the color merchants sold it under the name of *blanc ordinaire.* Merimée describes the Dutch process in the usual way, except, in referring to the temperature of the stack, he says the heat should not be allowed to go above 35° to 40° centigrade. The plates of lead that were used to cover the pots furnished the scales or flakes — the flake-white of the shops. The spirals which were placed in the pots were beaten after corrosion, and the corroded lead was ground in water and washed. The pulp was filled into conical earthenware pots and dried, taking the well known pyramidal form.

Merimée recommends the use of wetted chaff, or spent tan-bark, to avoid the discoloration often observed in the lead when stable-litter is used. Some manufacturers added to the vinegar substances capable of disengaging carbon dioxide.

In describing the manufacture of *blanc de Krems,* Merimée says the plates of lead are exposed to the vapors of vinegar and carbon dioxide in boxes of pine wood, which are rendered impervious to moisture by a coating of resin. The plates, bent in the shape of a chevron, are disposed upon laths suspended on a ledge placed in the interior of the boxes, the plates being separated from one another and from the sides of the box. To produce carbon dioxide the lees of wine or crude tartar are added to the vinegar; occasionally the same result is attained by the addition of bits of marble. The boxes are closed, and placed upon a heated flue, which runs around the room and carries the temperature to 30° centigrade, "above which it should not be allowed to rise, or the vinegar will evaporate too rapidly and much vapor will be lost. Fifteen days are required to

complete the operation, and the product, which is not as hard as that made by the Dutch method, does not require grinding, a simple levigation only being necessary. After washing, the pulp is filled into earthenware vases and dried in the same chamber in which it is produced." "*Blanc de Krems,*" this author confesses, "has less body than *blanc d'écailles,* because the molecules are more divided; but equal weight will cover a greater surface. When newly prepared it has a strong odor of vinegar." [1]

Merimée refers to the discovery by Thénard of a means of restoring to their original whiteness surfaces painted with white lead which have become discolored by the action of hydrogen sulphide. This process consists simply in treating the surface with oxygenated water. This water instantly converts the lead sulphide, which is black, — and which is formed upon the surface of white lead by the hydrogen sulphide, — into lead sulphate, which is white. It will be remarked that some of the writers of this period, in describing the Dutch process, caution against allowing the temperature to rise above what in more modern practice is considered a low range. Merimée mentions 35° to 40° centigrade. A reason for this precaution is given by a French writer on chemistry, M. Baudrimont, who says that when the temperature of the stack falls below 35° centigrade the ceruse becomes gray, because it contains some metallic lead; and if the temperature exceeds 50° it will become yellow; but he fails to account for this last phenomenon.[2]

An ingenious method for the preparation of white lead was suggested some years since by De Rostaing. He allowed a continuous stream of molten lead to fall upon a metallic disk, revolving at the rate of two thousand revolutions per minute. The lead was thrown with great force

[1] See J. F. L. Merimée, De la Peinture à l'Huile, pp. 222, 227 *et seq.*

[2] A Baudrimont, Traité de Chimie (Paris, 1846), vol. ii. p. 187.

tangentially to the circumference of the disk, and being hot was said to rapidly oxidize in its passage through the air. The lead was afterwards changed into white lead by the action of acetic acid and carbon dioxide.[1]

According to Leuchs the first factory established in France for the manufacture of white lead was located at Pontoise. The works of Lefêvre and Company, at Lille, were erected about 1825. The method in use here was the Dutch process. In 1829 there were other establishments in France for the manufacture of white lead by the Dutch method, notably at Paris, Orleans, and Vergennes; the production at the latter factory amounted in 1829 to 500,000 kilos. At Portillon, near Tours, the establishment of Messrs. Lallu and Delaunay had, according to Riffault, adopted the method of Thénard.[2]

The manufacture of white lead in France is at present suffering from the strong competition of the German and English makers, who, notwithstanding the protection afforded to the domestic manufacturer by a moderate import duty, are enabled, by their abundant supply of raw material and by more economical methods, to force the price of white lead in France to a point which admits of no profit to the home manufacturer. The works at Clichy are said to be no longer operated. The method of Thénard has not secured such a position in public favor as was predicted at the time of the exhaustive experiments and tests made in 1809, to show its superiority over lead made by the ancient process. At Lille, the most important seat of the industry in France, there are eight white-lead factories of considerable importance, and three smaller establishments. The larger factories now employ the Dutch method; one is said to produce 1,700 to 2,000 tons

[1] Abridgments of Specifications, etc., p. 228.

[2] See Riffault, A Practical Treatise, etc., p. 79 *et seq.;* also J. Ch. Leuchs, Traité Complet des Propriétés, etc., p. 7.

annually. There are several factories in the neighborhood of Paris.

Consul Williams says that the French manufacturers complain of the unprofitable character of the business. A syndicate of manufacturers, formed in Paris to sustain prices, was dissolved in December, 1886.[1]

[1] U. S. Consular Report, No. 75, Washington, 1887: Report of Consul Charles P. Williams, p. 580.

CHAPTER XV.

WHITE LEAD IN GERMANY AND AUSTRO-HUNGARY.

LEFORT says that the manufacture of ceruse passed from Venice to Krems, then to Holland and England. There seems to be good reason to believe that the industry was established in Germany as early as or perhaps before its introduction into Holland. A factory was established at Krems at a very early period, and its products became celebrated for excellence throughout Europe, under the name of *kremserweiss*. Watin refers to this product, and says it was much in favor. He describes Krems as "a little town in the Basse Autriche." It is possible that the manufacture was still conducted at Krems in Watin's time, 1774, though Leuchs, writing in 1829, says: "The name *kremserweiss* originated at the factory at Krems, but the factory has long since disappeared." Gentele says: "The origin of the name *kremserweiss* is doubtful, but the term has been used for very many years to distinguish the best white lead, and many German and Austrian manufacturers place it upon the very highest grades of their production."[1] Occasionally the term *kremnitzerweiss*, or *chremnitzerweiss*, is used instead of *kremserweiss*; but, as before observed, white lead has never been made at Kremnitz, and these terms or names are commonly used by German and Austrian manufacturers; but they invari-

[1] Lefort, Chimie des Couleurs (Paris, 1855); J. Ch. Leuchs, Traité Complet, etc., p. 7; Watin, L'Art du Peintre, p. 17; J. G. Gentele, Lehrbuch der Farbenfabrikation, p. 110.

ably distinguish the choicest productions when used by respectable and trustworthy manufacturers.

Boerhaave, in his "Elements of Chemistry," published in 1724, describes a laboratory experiment in making white lead, in which it is proposed to make lead acetate at the same time and in the same apparatus. He says a glass retort should be cut in such a manner as to leave a very long mouth; an alembic head of glass is then fitted to this, some vinegar is put in the body, and a number of thin plates of lead are placed in the head, in such a manner as to allow them to stand erect and somewhat apart. The body of the apparatus should then be set in a sand-bath for twelve hours. When unluting the apparatus, the receiver, which has been fitted to the head, will be found to contain a sweet styptic liquor, turbid and nauseous, called the acetate of lead; and the plates of lead will be found to be covered with a white, dusty matter, which is ceruse.[1]

A process of making white lead is described in Zedler's "Universal Lexicon," edition of 1733. It is probably the method in use in Germany at that time. This description varies but little from the practice in Holland and England at that period. The lead was cast in sheets, rolled in spirals, and placed in earthen pots over vinegar; the pots were then sealed and put in a warm place for four weeks. The whitest and most brittle portions of the resulting white lead, "those pieces thoroughly corroded within and without," were put aside to be sold to the artists. Other portions were ground with water and formed into "blocks like pyramids, and were wrapped in blue paper rather than any other color, so that the white will seem yet whiter." In these papers, it is said, the white lead was sent to Holland and England.[2]

[1] Hermann Boerhaave, Elements of Chemistry, London, 1735.

[2] Zedler, Universal Lexicon, vol. iv., article Bleiweiss.

In 1758, according to Von Justi, the demand for white lead in Prussia was greater than the manufacturers were able to supply. This author describes two methods which may be employed, but in each these "two conditions must be observed: first, the lead must not be allowed to touch the acid; and second, a gentle heat is necessary to volatilize the vinegar." The first method is described as being purely that of distillation. It is recommended that vessels of tin be employed instead of copper or iron, which would be attacked by the acid, or of earthenware, which are too fragile. The still or vessel was provided with a suitable and rather tall cap and the requisite tubes. It was half filled with good wine vinegar, above which the lead was placed, cast in sheets and rolled, and supported so that it did not touch the vinegar. Thus prepared, the vessel was exposed to a gentle heat over a slow fire, to volatilize the vinegar. This warming was repeated several times until the sheets of lead were entirely corroded and transformed into white lead. The second method is described as being much the same as the first, except that the vessel is entirely closed, and the heat used is much less, so that the vapors, condensing in the upper part of the vessel, fall back into the bottom, carrying with them some lead in solution, which was afterwards utilized in the manufacture of lead acetate. In these cases substances capable of disengaging carbon dioxide were doubtless present in, or added to, the vinegar.

The corroded lead was "rubbed in very gentle fashion" upon huge stones, and at the same time moistened with water, forming a pulp, and then moulded into pyramidal shapes and dried in the air in summer, and in a moderately heated room in winter. Von Justi remarks upon the gross adulterations practised by the English and Dutch. In England and in Berlin, he informs us, a portion is unadulterated, but in that case it is called *schieferweiss* or

schulpweiss, in Latin *cerussa lamellata.* "Those," he says, "who imagine that *schieferweiss* is composed of *tin* are mistaken. The *schieferweiss* of commerce is nothing more nor less than the best and purest white lead, with no trace of tin."[1] In these descriptions Von Justi appears to follow Boerhaave in his account of the manufacture of white lead by the process he calls distillation.

Von Justi also describes the process in use in the factory at Berlin, which was the same as is described by Jars as practised at Amsterdam and at Rotterdam. Von Justi adds the curious statement that "the workmen who have had the most experience in the manufacture declare that stallion-dung is the best for the purpose of fermentation, and are careful never to use that of mares.

It was the custom at that early period with some manufacturers to grind white lead in vinegar for the purpose of making it whiter. They had authority for this in the recommendation of Fra Fortunato, of Rovigo, in 1659,[2] and the practice has not been entirely abandoned in Germany and Italy since that time. White lead, after being ground in oil, was packed in earthen jars, and the tops were covered with water three or four inches deep, to preserve the color and "to prevent the formation of the skin which would be so troublesome."

Krünitz says that white lead was used as a basis for all colors. "It has more consistence, and makes a finer and more brilliant white; it makes all other colors better, because it covers better and makes them go further; and besides, it dries more easily. There is no advantage in adulteration, because pure white lead allows you to cover a surface with less quantity, and so in the end goes further than the adulterated."[3]

[1] Von Justi, Vollständige Abhandlung, etc., p. 518 *et seq.*

[2] See Mrs. Merrifield, Original Treatises, etc., p. 151.

[3] Johann Georg Krünitz, Oeconomische Encyclopedie, 1787, vol. v. p. 718 *et seq.*

The Dutch method was in general use in Germany until comparatively recent times, and stable-litter was employed as the source of heat and carbon dioxide; it has been superseded, however, by the chamber process, or the German method, as it is generally termed. This modification of the Dutch process consists in substituting specially built closed chambers for the stack or bed, and artificial heat for the heat generated by the decomposition of masses of stable-litter, or spent tan-bark, or other organic substances, as used in the Dutch process. Sometimes, however, the floors of the chamber in which the lead cast in sheets and suspended on laths is placed are covered with spent tan-bark, or other fermentable material, which is saturated with vinegar, — this arrangement furnishing the gases necessary for the conversion of the lead, as well as the heat, which is also a prime factor in this transformation. Occasionally the plates of lead are suspended within wooden boxes which contain the acetic acid, the boxes being ranged along the floor of the closed chamber. It was formerly customary to mix with the acid wine lees, carbonate of potash, bits of marble, or other substances capable of disengaging, during decomposition, carbon dioxide. In later times this necessary element in the production of true white lead has been obtained from the combustion of coal, coke, or charcoal, or by other means, but it must be properly washed and purified before passing into the chamber.

The manufacture of white lead by the Dutch process was established at Klagenfurth, in Carinthia, as early, it is claimed, as 1760. A modification of the Dutch method, called by Gentele the "Klagenfurth process," was substituted for the old method in 1835. This new process has since been adopted by manufacturers at Villach, St. Veit, Wolfsberg, and at other places in Carinthia. The product of these factories has the reputation of being of very

superior quality, not attributable perhaps altogether to the method employed in the manufacture, but in part to the excellence of the metallic lead produced in the district, — the celebrated "Villacher" lead from the mines at Bleiberg.

The Klagenfurth process is a modification of the Dutch method. The vapors of acetic acid, and of carbon dioxide, in an elevated temperature, act upon metallic lead. The modification consists in the manner of producing the carbon dioxide, the acetic acid vapors, and in artificially heating the chamber, or stack.

The manufacture is conducted in solidly built closed rooms provided with double floors. The first floor, which is the ground floor, is occupied by a furnace, so arranged as to be fed from the outside; the stone flue of this furnace passes on the ground from one end of the room to the other, and then passes up through the upper room and the roof to the outer air. This furnace, with its flue, is used for heating the upper room. The upper floor is formed of boards, loosely put together in order that the heat from below may freely pass into and warm it. Upon this floor water-tight boxes are placed, with spaces between and around them so that access may be had to them at all times. These boxes are provided with strong covers, which are pierced with holes to allow free passage to the gases which may be evolved from their contents. A strong framework is erected upon these boxes extending quite to the roof, and so arranged as to carry short sticks, upon which the lead, previously cast in long and thin plates and bent, can be hung. When the framework over the boxes is filled with lead, the spaces between the boxes are also filled; this is accomplished by placing sticks across the passageways, resting them at either end upon the framework. This operation is continued until the chamber above the level of the boxes is completely filled with plates of lead hung upon sticks. The work-

men then fill into the boxes a quantity of vinegar, and also a quantity of the extract of raisins, or dried grapes. The fires are now started, and the heat, ascending to the upper room, in which the boxes containing the liquid mixture and the plates of lead are arranged, gradually warms the contents of the boxes, and the vinous fermentation begins in the sweetish fluid; this reaction disengages carbon dioxide in considerable quantities. The acetic fermentation also starts in the alcohol produced by the vinous fermentation; thus both reactions are in process at the same time. The heat also volatilizes the vinegar, and in a short time the chamber is filled with the vapors of carbon dioxide, of acetic acid and steam; the lead is warmed, and all the conditions demanded by the Dutch method are present. The workmen enter the chamber from time to time to stir up the mass in the boxes, to draw off the vinegar if it becomes too concentrated, and to add fresh material as it is needed.

The resulting product is exceptionally clean and white. The carbon dioxide produced by the vinous fermentation is free from soot, hydrogen sulphide, and other deleterious impurities so common to this substance when produced by the combustion of coke or of other forms of carbon. Much of the white lead as it is formed flakes off and drops upon the boxes or upon the floor, rendering it necessary to use extreme care on the part of the workmen to avoid staining or injury to the color of the product.[1] Gmelin refers to what he terms a new German method. This is perhaps the original chamber method introduced into Germany. Plates of lead were suspended in wooden boxes into which a quantity of vinegar had been poured. The boxes were arranged in closed chambers. The floors were covered with spent tan-bark wetted with vinegar. These chambers were artificially heated, and the vapors

[1] J. G. Gentele, Lehrbuch der Farbenfabrikation, p. 135 *et seq.*

of acetic acid produced by the heated vinegar, and of carbon dioxide evolved in the decomposition of the tan-bark effected the corrosion of the lead.[1] According to Preschel, white lead was made at Frankfort early in this century by precipitation, or the Thénard process.[2] This method is still in use, it is said, in some factories in the Rhenish provinces.

An ingenious process was suggested by Schuzenbach, of Freiburg. He placed in a heated chamber wooden tubs which were filled alternately with layers of shavings wetted with acetic acid and with plates of lead. The tubs were kept closed for a time, and then opened and the plates of lead removed. The white lead which had formed upon the plates was washed off, the shavings moistened again with acid, the uncorroded lead replaced, and the operation renewed.[3]

At Eisenach, the manufacture of white lead is now conducted by what Gentele terms the "Dampfloogen," or steam-chamber, process. This also is a modification of the Dutch method, and is considered to be an improvement on the Klagenfurth process. It is referred to by some writers as a new invention, but it differs in no essential particular from the method patented by Sir James Creed, in England, in 1749, nearly a hundred years earlier than the date of its introduction in Germany.

A series of rooms are arranged in a strong building, having heavy walls of brick or stone; each room has an arched roof of stone or slate and is provided with a false floor, some five feet above the main floor. In this space between the floors furnaces are erected to provide carbon dioxide by the combustion of fuel, and vapors of acetic acid

[1] Gmelin, Handbook of Chemistry, vol. v. p. 118.

[2] J. S. Preschel, Technologische Encyclopedie (Stuttgart, 1830), vol. ii., article Blei.

[3] Riffault, A Practical Treatise, etc., p. 111.

by heating dilute vinegar in open kettles, or by other suitable means. The lead is hung in the upper compartment in a manner much the same as at Klagenfurth; apertures are provided, to be opened or closed at pleasure, for the admission of fresh air. The chambers when filled contain from ten to fifteen tons of metallic lead, cast in long thin plates and hung over laths or sticks.

When the chamber is completely filled with lead the window-blinds and doors are closed, the fire is started under the receptacle containing the dilute acetic acid, and fresh air is allowed to flow in and mix with the acetic acid vapors. After two or three days the lead will be found to be covered with drops of moisture, and basic lead acetate is formed; carbon dioxide is now sent into the chamber, and the supply of fresh air is partly shut off; the fires are kept up and the temperature rises until it reaches 70° or 90° centigrade (158° to 194° Fahrenheit). These conditions are steadily maintained, the workmen examining the condition of the lead from time to time and regulating the flow of acid vapors, of carbon dioxide, or of air, as experience teaches produces the best results. In about three weeks the lower plates, or leaves, of lead are corroded and fall upon the floor, and in six or seven weeks there is very little lead left unconverted. When the operation is completed the fires are drawn, the chambers cooled, and the lead is removed from the floor and taken to the mill for separating the corroded from the unconverted metallic lead. It is then washed, ground, and dried, in the same manner as white lead made by the Dutch process. When the operation has been successful it is found that from 80 to 90 per cent of the metallic lead has been converted into white lead.[1]

This method, or modifications of it, is generally used in Germany to-day, having been substituted for the older

[1] J. G. Gentele, Lehrbuch der Farbenfabrikation, p. 138 *et seq.*

Dutch process. In the United States attempts to establish a modification of the Dutch method known under the name of "the chamber process," which is practically the same as the German method, have resulted disastrously. The products of this method have not been as uniform as those made by the Dutch process, and a prejudice has persisted against them. It has been demonstrated also that there is no economy in their use over the old method. This may be accounted for by the plentiful supply and the comparative inexpensiveness of spent tan-bark and stable-litter in the United States, — conditions which perhaps do not exist in Germany, where these substances may be of much greater value. The failures in the United States may possibly be largely due to a lack of experience in the experimenters in the manufacture of white lead; and besides, those who have made the attempt have labored under the heavy disadvantage of being obliged to establish a demand for a new and untried brand.

There seems to be no good reason why white lead of as excellent quality should not be made by these processes as by the Dutch method, but the experience of practical men who have used the products of these modified methods has been unfavorable, and it is certain that a renewed attempt to introduce them here would be attended with much discouragement. The German manufacturers, however, have succeeded in thoroughly establishing their new methods, and manufacture large quantities of white lead by these new processes which they sell in the principal markets of Europe. It is possible that long experience and great care have enabled them to overcome difficulties which have been encountered by those who have attempted to introduce new methods on this side of the Atlantic, and to produce white lead equal in quality to that prepared by the ancient process; but their productions are not in great favor in some of the European markets, and

are frequently sold at a less price than old-process white lead.

Kremserweiss is made at Klagenfurth by simply drying the white lead which falls from the suspended plates upon the floor, and which is saturated with acetic acid, in suitable moulds. In the Rhine provinces this article is prepared as follows: the white lead made by the steam-chamber process is treated with vinegar and water, and the slime which rises to the top is removed. More vinegar is added and the mass is agitated. This process is repeated several times. Finally it is treated with a hot solution of lead acetate, settled, and the pulp is introduced into moulds where it is dried. This method is said to produce a beautiful white kremserweiss, which breaks with a fine glassy fracture.[1] The hard and brittle character of dry white lead prepared in this manner was in former times considered as a proof of its genuineness.

In some German factories white lead, after it is ground and washed, is mixed with a cementing material, such as isinglass, gum-water, or similar substances. It is then made into tablets, when it is termed "kremserweiss;" or it is formed into little pyramidal shapes, which are wrapped in blue paper and called Venetian white lead. In some German and Austrian factories all perfectly pure white lead is termed "kremserweiss," and that adulterated with barytes, or other substances, is called "Venetian" white lead; a still greater degree of debasement is indicated by the terms "Hamburg," or "Dutch" white lead.

In 1835, the manufacture of white lead had been considerably extended in Germany and Austria. Important factories existed at Vienna, Klagenfurth, Villach, Schweinfurt, Osterode, Eisenach, Dresden, Heilbron, Breslau, and Berlin, where a factory was in operation, according to Von Justi, in 1758. White-lead factories were established at

[1] Gentele, Lehrbuch der Farbenfabrikation, p. 151.

Dresden about a hundred years ago. The method originally employed was the Dutch process, but in comparatively recent times this method was abandoned and the chamber process was substituted. The Rhine district is now one of the most important seats of the industry in Germany. It is estimated that the production in this district amounts to about seventeen thousand tons annually. Of this more than ten thousand tons is exported to Great Britain, Holland, Belgium, France, Sweden and Norway, Denmark and Austria, but principally to England.

It is quite impossible to arrive at any trustworthy estimate of the production in Germany through the consular offices of the United States. Consul General Raine says that German manufacturers were cautioned, a short time since, by a semi-official article in the German press against giving such information, especially to foreign consuls.[1] The importance of this industry, in sympathy with the recent uprisal of commercial Germany, has very greatly increased, until at the present time German white lead, owing to the proximity of the factories to abundant supplies of raw material, to cheap labor, and to the enterprise of German manufacturers, is found in all the principal markets of Europe, and is closely competing with and pushing English productions not only in foreign markets but in London itself.

Replies to inquiries made in Germany through London merchants having intimate business relations with German manufacturers indicate that the production of white lead in Germany in 1886 reached forty to fifty thousand tons. About twenty-five thousand tons were required for domestic consumption, and the remainder found a market in other European countries.

[1] See U. S. Consular Reports, Nos. 73 and 74, Washington, 1887: Reports of Consul Warner, p. 59; Report of Consul General Raine, p. 500; Report of Consul Mason, p. 503.

CHAPTER XVI.

WHITE LEAD IN THE UNITED STATES.

THERE was but little need for the establishment of white-lead factories in the United States until after the Revolution. The simple habits of the first settlers, their poverty, and their struggles for subsistence prohibited the use of paints for decorative purposes, while the abundance of timber rendered it unnecessary to be at any great expense to preserve it from the destructive action of the elements. Indeed, the spirit which pervaded society, in some of the colonies, regarded the use of articles of ornament or luxury as tending to loose or to aristocratic ways of living, which would endanger the morals of the community. The use of paint, therefore, was discouraged by the early settlers. Bishop relates the case of the Rev. Thomas Allen, of Charlestown, near Boston, who was "called to account" in 1639 for having paint about his dwelling. The reverend gentleman secured immunity from correction by assuring the authorities of his condemnation of the practice of using paint, and by proving that the offensive substance had been applied by a former proprietor, and was there when he took possession of the premises.

The dwellings of the early settlers were generally of wood, unpainted on the outside and inside. The interior walls were occasionally whitewashed, but beyond this no decoration was to be observed. The first church in Boston (destroyed by fire in 1711) was never painted, it is said, inside or outside. In 1705, according to Bishop, the coat

of arms of Queen Anne, in the Court-House at Salem, Mass., was ordered to receive "a coloured covering," which is said to be the first reference to art in that quarter. A list of mechanics made in 1670, in Massachusetts, fails to show the name of a single painter. Painters' colors, however, were for sale in Boston in 1714.[1]

One of the enterprising merchants of Philadelphia during the period of the Revolution was Mr. Samuel Wetherill. He appears to have directed his attention at first to the manufacture of cotton and woollen cloths, of which the colonies, and especially the Continental army, soon after the outbreak of hostilities, were in sore need. Previous to the war, most manufactures, of prime necessity as well as of luxury, were obtained from England; but the war closed this source of supply, and importation from other European nations was attended with such risks that but little was brought in. The consequence of this state of affairs was the rapid increase in the value of clothing, and the scarcity became a source of great embarrassment to Congress who required large supplies for the army. In March, 1776, that body recommended the assemblies of the colonies to encourage the culture of flax and cotton and the growth of wool, and to establish in each colony a society for the Improvement of Agriculture, Arts, Manufactures, and Commerce.

In compliance with the recommendation of Congress, societies were formed in the colonies in the early days of the war for the encouragement of manufactures. To one of these societies Mr. Wetherill belonged, and when the "Pennsylvania Society for the Encouragement of Manufactures and the Useful Arts" was established, in 1787, he became one of its most prominent members. This society offered premiums for the invention of labor-saving machines, for the raising of hemp, cotton, and flax, and for

[1] See Bishop, History of American Manufactures, vol. i. p. 208 *et seq.*

excellence in the quality of various articles of manufacture produced in the State. Whether or not the society offered a premium, or assisted in any way in the establishment of the first white-lead factory in the State, does not appear,[1] but that Wetherill was one of the active promoters of manufacturing enterprises is shown by the fact that in the autumn of 1788 he was chairman of the manufacturing committee of the society. In May, 1777, Wetherill had a factory in Philadelphia for the manufacture of woollen and cotton cloths, and later the firm of Samuel Wetherill & Son established the manufacture of chemical products, and imported and sold dye-stuffs, chemicals, white and red lead, etc. They began the manufacture of white lead in Philadelphia in the first decade of this century. Bishop places the date at 1789, but Mr. W. H. H. Wetherill, a descendant in the fourth generation, fixes the actual beginning of corroding at 1804. The new enterprise excited the jealousy and ire of the English manufacturers who had supplied the markets of the country, and there is a tradition that the destruction of the factory by fire, soon after operations were begun, was the work of a young Englishman, who applied for work a few days before the disaster, and who left for home in a vessel which sailed for London early in the morning of the day following the fire. The factory was not rebuilt until 1808 or 1809. During its erection an agent of the English white-lead factories frequently warned Wetherill of the danger of the undertaking, and confidentially informed him of his orders to crush the new enterprise. Nothing daunted, Wetherill completed the factory, and operations were begun; but, true to his instructions, the agent of the English companies immediately put the price of his commodities to such a point that absolute ruin to Wetherill seemed inevitable. The war of 1812, however, forced the English manufacturers to retire, and

[1] See Bishop, History of American Manufactures, etc., vol. i. p. 407 *et seq.*

insured the success of the new enterprise. The products of this factory were soon in much favor, being considered quite equal to the English.

Wetherill employed the Dutch method in the preparation of white lead, using stable-litter as the source of heat. He took out patents in 1811 "for setting the beds or stacks" and for an improved method of screening and separating the corroded lead. He cast the lead in sheets and rolled it in spirals, before placing it in the pots, as the custom was in Europe at that time. The destruction by fire of the early records of the Patent Office renders it impossible to ascertain the details of Wetherill's improvements. He seems to have been thoroughly able and enterprising, and made important improvements in the manufacture of red lead.

The importance of manufacturing interests was as thoroughly understood in Pennsylvania at that early day as at the present time, and through the influence of some of its citizens Congress was induced to inquire into the condition of manufactures in the country at that time. In an elaborate report to the Secretary of the Treasury, Mr. Coxe says: "Soon after the acquisition of the southern lead mines (Louisiana had been purchased some years earlier), establishments to make pigments of that material were erected in one season sufficient, with the shot factories, to employ that portion of the addition which was likely to reach Atlantic ports. Red and white lead, and patent yellow, are now made in considerable quantities." In a list of the industrial establishments in the United States accompanying this report, which is for the year 1810, but one white-lead factory — producing in that year three hundred and sixty-nine tons — is mentioned.[1] This was probably Wetherill's factory.

[1] Tench Coxe, A Statement of the Arts and Manufactures of the United States, prepared by instruction of Albert Gallatin, Esq., Secretary of the Treas-

The enterprise of Wetherill was closely followed up. White-lead works are said to have been established in Philadelphia previous to the war of 1812 by an Englishman named Smith, who was succeeded in 1813 by Joseph Richards. Richards continued in the business until 1819–20, when his establishment was acquired by Messrs. Mordecai Lewis and Company, merchants, who were dealers in and importers of white lead as early as 1772. Richards took out a patent for improvements in the manufacture of white lead in 1818, and he was probably connected with the business as late as 1836, as he received a patent in that year for "a new method of making white lead." Chemical works were established in Philadelphia during, and perhaps prior to, the Revolution, but they did not assume much importance until the War of 1812, when the interruption in the receipt of supplies from Europe increased the price, and enabled American manufacturers to establish themselves upon a substantial basis. Mr. John Harrison had begun the manufacture of sulphuric acid in Philadelphia, at what is now known as the Kensington Works, prior to 1806. In that year the works were destroyed by fire, but were immediately rebuilt. Harrison was an enterprising manufacturer, and is distinguished as being the first in this country to use a platinum still for the concentration of sulphuric acid. The manufacture of white lead was begun at the Kensington Works shortly after they were rebuilt, but it is impossible to assign a date for this event. Mr. Thomas S. Harrison, a descendant and successor in business to Mr. John Harrison, says, in reply to an inquiry upon this subject: "Tradition says that corroding by the Dutch process was begun upon the completion of the new works."

Philadelphia was unquestionably the first seat of the

ury, given by him in obedience to a resolution of Congress of March 19, 1812 (Philadelphia, 1812), p. 42.

manufacture of white lead in the United States, and one or more factories were established there prior to 1810. The production of white and red lead in this year is stated by Bishop to have been 500 tons. The imports, however, amounted to 1,150 tons,[1] and American enterprise probably found it a hard struggle to contend against the English manufacturers, who endeavored to strangle the infant industry. The manufacturers appealed to Congress for protection and support, and suggested that the duty of one cent per pound on pig-lead be removed, and that a duty of two cents per pound be imposed upon white and red lead.

The method used in these early factories was the Dutch process, and the industry increased in importance during the progress of the war. Prices advanced to such an extraordinary figure that public attention was strongly attracted to this branch of manufacture, and several attempts were made to improve the methods employed and to shorten the time required to produce the perfected product. In 1814 Welch and Evans, of Philadelphia, patented a quick process of making white lead, by which granulated lead was placed in lead-lined barrels, which were made to revolve. The barrels were partly filled with water, and the particles of lead removed by attrition were oxidized by oxygen from the air, and this oxide was carbonized by the introduction of carbon dioxide produced from burning charcoal. Richards, who sold his Philadelphia factory to Lewis, joined Evans in building a factory near Philadelphia to make white lead by this process. The venture proved unprofitable, and after a short season of disaster it was abandoned. Hagner, in 1817, and Clark, in 1818, both of Philadelphia, took out patents for improvements in the manufacture of white lead, probably methods by which the time necessary for conversion was shortened. Of

[1] Bishop, History of American Manufactures, vol. ii. p. 155.

Hagner we have no records, unless he appears as a member of the firm of Gregg and Hagner, engaged in the manufacture of white lead in Pittsburgh, in 1837. Clark was probably the promoter of the works established at Saugerties, New York, in 1832, of which mention will be made hereafter.

The manufacture of white lead was established at Pittsburgh in 1810 by Adam Bielin and J. J. Stevenson. In the same year Trevor, Pettigrew, and Provost erected a second factory for the manufacture of white and red lead. This firm also manufactured acids. They retired from the white-lead business after a short experiment probably, as in 1813 the factory of Bielin was the only one in active operation in Pittsburgh.

There are no records extant by which the process employed in these Pittsburgh factories can be determined. Probably the Dutch method was used, as up to this date the only patent recorded except Wetherill's, who certainly used the Dutch method, was taken out by A. J. Hamilton, of New York, in 1813, for the manufacture of white lead and flake-white. The specifications of this patent were burned. Hamilton's name does not appear afterwards, and his improvements were probably unimportant.

In 1815 the Cincinnati Manufacturing Company had a factory for the manufacture of white lead in operation in Cincinnati.[1] This is said to have been the third white-lead factory erected west of the mountains. Its products were claimed to be superior to the best English, "as they were entirely free from whiting."

Bishop says that a factory for the manufacture of white lead existed in New York in 1820. Several small plants for grinding white lead and colored paints were established in that city from 1800 to 1825, but the white lead used was of European production. The earliest notice of the

[1] Bishop, History of American Manufactures, vol. ii. p. 218.

manufacture of white lead from the metal is of the operations of Dr. Vanderberg, of Albany. Dr. Vanderberg was a man of more than ordinary ability, and was noted for his scientific acquirements. He attempted the establishment of the manufacture of white lead in New York in 1820 to 1824 by a short process. His means proving insufficient, he made the acquaintance of Augustus and John Bell Graham, who were operating a distillery in Brooklyn. They were induced to join Vanderberg in his operations. A short experience demonstrated the profitable nature of the business, but also showed that their capital was inadequate. They laid their plans before Mr. David Leavitt, at that time a successful merchant, and engaged in the wholesale grocery business in New York. Mr. Leavitt decided to embark in the business, and the Brooklyn White Lead Works was incorporated, with Mr. Leavitt as president and the Grahams as secretary and treasurer. They erected works on the site of the distillery, and began at once the manufacture of white lead. It was soon found that the process adopted by the new corporation was defective, the product being irregular, and about 1830 it was abandoned, and the old Dutch method was substituted, stable-litter being used as the source of heat and carbon dioxide. In 1832 Mr. Augustus Graham visited Europe, and succeeded in getting employment, as a workman, in one of the best-appointed factories in England, where he learned the processes and methods of the English manufacturers. On his return to New York these were adopted, including the substitution of tan-bark for stable-litter. The products of this company at once took a high position in public favor, and the business has been continuously and successfully conducted, upon the same premises, and under the same name, to the present time.

The Union White Lead Company, of Brooklyn, was established about 1827 to 1830, by the Messrs. Cornell,

who at first began grinding white lead of foreign manufacture; they shortly added the preparation of white lead from the metal, and conducted a profitable business for many years. The Cornells had long been connected with Hinton and Moore, of New York, who were the largest dealers in the city; they ground white lead of English make, and were noted for their enterprise and sagacity.

The manufacture of white lead was begun in Salem, Massachusetts, in 1824, by The Salem Lead Manufacturing Company. The process employed is said to have been a German method, probably a modification of the Dutch process, termed in the United States, the "chamber process." In 1826 Francis Peabody established the manufacture in Salem, Massachusetts, and conducted an extensive and successful business for many years. He employed the Dutch process, and found it necessary in 1830 to erect important additions to his plant. Besides supplying a continually increasing home demand, he exported white lead in considerable quantities. Peabody continued until 1843, when he relinquished the business to The Forest River Lead Company which was organized to succeed him. There appears to be some doubt respecting the date of the establishment of the manufacture of white lead in Cincinnati. Bishop says the Cincinnati Manufacturing Company had a factory in operation as early as 1815. Another authority states that Barney McLennon established the business in 1820, at the corner of Central Avenue and Front Street. In 1828 Robert McCandless and Richard Conkling engaged in the manufacture of white lead in Cincinnati, employing the Dutch method. They cast their lead in sheets and rolled it in spirals, as was the custom in England and Holland. In 1830, McCandless retired from the business, and Conkling became the sole proprietor. In 1829 A. McBurney, of New Haven, Ohio, secured a patent

for an improvement in the manufacture of white lead. The specifications of this patent were destroyed by the fire at the Patent Office, and there is no record of McBurney's operations.

The consumption of white lead in the United States prior to the war of 1812 was limited and was chiefly supplied from Europe; the quantity made at Philadelphia was very small. White lead sold at from ten to twenty cents per pound, and the English, and probably the American white lead, was largely adulterated. During the war the product of the American lead mines was insignificant, and utterly inadequate to supply the demand. The Galena district was still in the possession of the Sacs and Foxes. The mines in Missouri were undeveloped and the mines in the Eastern States yielded but a limited supply. The suspension of the importation of pig-lead caused an extraordinary advance in the price of this article and of all its products; white lead sold for as much as thirty cents per pound. The enormous profits indicated by these extreme prices stimulated the erection of factories, and the invention of ingenious men to devise some shorter and less expensive way of manufacturing than by the old Dutch process which had hitherto been employed. Metallic lead, which reached such an enormous value during the war, rapidly declined at its close. The removal of the Indians, who had held possession of the Galena lead fields, and the decision by Congress to sell the mineral lands, stimulated mining operations, and in a few years the production of metallic lead was in excess of the demand. The price of this substance fell, until in 1830 it sold for less than four cents per pound. The revival of general business after the war resulted in the establishment of several white-lead factories. The decline in value of metallic lead, and the sharp competition occasioned by the increase in the output of the older factories, added to the product of the new establish-

ments, caused the value of white lead to decline to twelve cents per pound in 1826, and to nine cents in 1830.

In 1830, the manufacturers of the Eastern cities of the United States found it necessary, owing to very strong competition, and probably overproduction, to enter into an agreement for the purpose of maintaining uniform and profitable prices. By the terms of this agreement each factory (there were eight at that time east of the Alleghanies) had the privilege of appointing an agent in eleven principal markets in the Eastern States, from Portland to New Orleans. These agents were to receive a commission of five per cent. The prices and terms fixed by this agreement were as follows:[1] —

Dry white lead	8	cents	per pound.
Pure lead, ground in oil	9	"	"
Potters' red lead	6	"	"
Glassmakers' red lead	7¼	"	"

The terms were, —

For quantities amounting to —

Less than $300	6 months		
From $300 to $500	6 "	and 1%	discount.
" $500 to $800	6 "	" 2%	"
" $800 and upwards	6 "	" 3%	"

It was stipulated that these amounts were to be purchased at one time to entitle the buyer to the terms.

The parties to this agreement bound themselves in the sum of two thousand dollars, to be considered and treated as stipulated damages, for the full and faithful performance of the agreement, and ninety days' notice was required to be given of an intention to withdraw.

The signers to this agreement were Lewis and Company, Wetherill and Sons, Harrison and Brothers, of Philadelphia; Hinton and Moore, of New York, who were possibly selling agents for the Union Company, the Brooklyn White

[1] The price of pig lead at this time was about four cents per pound.

Lead Company, of Brooklyn, New York; and Francis Peabody, and The Salem Lead Manufacturing Company, of Salem, Massachusetts.[1]

The Eastern corroders entirely ignored their brother manufacturers west of the Alleghanies, in forming their syndicate; indeed there was scarcely any competition between the two sections. The mountains were a serious obstacle to the transportation of such a commodity as white lead. Pig-lead was floated down the Mississippi in flat-boats to New Orleans, and thence carried by ships to New York and Philadelphia; but this method of transportation is not adapted for moving white lead. At this time there were two or more factories at Pittsburgh, and one, perhaps two, at Cincinnati.

There are no trustworthy data by which the product of the ten or twelve establishments in existence in 1830 can be estimated. Probably three thousand tons would fully cover the annual production.

The decade following 1830 exhibited considerable activity in the establishment of new factories. The rapid growth of population in the West, and the almost universal employment of wood in building, rendering a coating of paint necessary for preservative as well as for decorative purposes, resulted in a great development of the industry in that quarter; while in the East, the financial success of the early establishments encouraged the erection of new factories. In Boston the establishment of the Boston Lead Company, in 1831, inaugurated the manufacture of white lead in that city. In 1835, The Salem Lead Manufacturing Company, which had been producing white lead by a chamber process for some years, relinquished business.

In 1832, the manufacture of white lead was begun at

[1] Mr. John T. Lewis, of Philadelphia, who courteously furnishes this interesting item, says he is unable to say how long this agreement lasted, but in 1834 a new one was executed.

Saugerties, New York, where an abundant supply of pure water, furnishing ample power, seemed to invite the establishment of the industry. The Great Falls Manufacturing Company was established at about this time, with Colonel Edward Clark as president, — the same Clark, possibly, who, in 1818, as a citizen of Philadelphia, took out a patent for an improved process for making white lead. This process (the specifications are lost) was probably a quick process; but Clark, in 1839, took out two patents for improved methods of separating corroded from uncorroded lead: one, by passing it upon an endless apron of wire cloth, under a whipper, "the quick and violent operation of which separates the carbonate from the metallic lead;" the other is described as "passing the partially corroded lead between rollers adapted to bend, indent, corrugate, and stretch the lead, thus separating the corroded from the metallic lead."

Jewett, Sons, and Company became interested in the manufacture of white lead at Saugerties about 1838. The process employed was a modification of the Dutch method, the exact nature of which the successors of this house are unable to state. Charles Ripley, of Saugerties, was granted, in July, 1837, a patent for a chamber process, described as follows: "Lead in sheets is bent into coils, and placed on shelves or slats, or suspended in the corroding-chamber. Vinegar is placed in steam-heated troughs in the corroding-chamber, and evaporated by the action of heat. Carbonic acid gas and oxygen (air) are supplied to the chamber, etc." The experiment of the Jewetts at Saugerties was abandoned after a short trial.

In the West, the single establishment recorded as existing in Pittsburgh in 1817 had no less than seven companions twenty years later. The operations of these factories were limited; as but nine hundred tons, it is estimated, covered their aggregate annual production. The business was prob-

ably unprofitable; the names of the proprietors entirely disappeared from the list of makers of white lead during the next twenty years.

There are no records existing by which the processes used by these manufacturers can be ascertained. The name of G. F. Hagner occurs in the records of the Patent Office as the recipient of a patent, in 1817, for a new process of making white lead; and it is probable that he was a member of the firm of Gregg and Hagner, who were one of the eight Pittsburgh manufacturers. Hagner's method was a short process.

In the far West the consumption of white lead was extremely insignificant in early days. The country was sparsely settled, and means of communication, except by the rivers, were irregular and expensive. The American pioneer affects but little the civilizing influences of paint; if the *chinks* between the logs of his cabin are well filled with mud he is content. St. Louis, Missouri, was "on the border" in 1837, when an establishment was erected for the preparation of white lead by Reed and Hoffman. These gentlemen after a short experience disposed of their plant to Charless and Blow, and soon after, Mr. Henry T. Blow retired from the firm, and accepting the factory as his share, devoted his untiring energies to founding the great corporation which, under the name of The Collier White Lead and Oil Company, exerts a powerful influence in the business to-day. The location of this establishment, contiguous to the lead mines of Missouri and Galena, gave it at once great advantages over its rivals in the cost of its productions; but the demand for paint increased but slowly, and the annual production, previous to 1850, did not exceed five hundred tons.

In Cincinnati, the establishment of the Conklings had a companion in 1836, when Mr. Townsend Hills erected a plant.

Several patents were granted in this decade for improvements in the manufacture of white lead. These improvements were generally in the direction of shortening the process, but none presented any novel features and none have survived.

The period of depression in the mining interests, noticed as occurring about the year 1830, continued for a year or two, and was succeeded by more favorable conditions. The price of metallic lead advanced until 1837, when the average value was about six cents per pound. White lead also increased in price, and sold at twelve cents per pound. From this time, however, values declined until 1840, when the metal sold at five cents per pound, and white lead at ten cents. The production of white lead in the United States in 1840 was probably about five thousand tons.

Between the years 1840 and 1850 the white lead industry in the United States developed rapidly. During this period, several establishments were founded which became in time classed among the largest and most important in the world. The Atlantic White Lead Company of New York was founded by Mr. Robert Colgate. John Jewett and Sons erected extensive works on Staten Island, New York. Battelle and Renwick acquired the works of the Great Falls Manufacturing Company, of Saugerties, and established the Ulster White Lead Company. The Suffolk Lead Works and The Norfolk Lead Company were established at Boston. The Forest River Lead Company, at Salem, succeeded to the business of Peabody. The industry was established at Buffalo, New York, by Thompson and Company. At Pittsburgh, B. A. Fahnestock and Company erected works and laid the foundation of a large business in the Northwest. Conkling, at Cincinnati, erected another plant, and called it The Eagle White Lead Works. In St. Louis, Mr. William Glasgow, Jr., erected works for the manufacture of white lead by the Dutch process; his

superintendent was Isaac Gregg of Pittsburgh, possibly the senior member of the firm of Gregg and Hagner who were engaged in the business there in 1837. Mr. Glasgow experimented with sawdust as the source of heat and carbon dioxide, hoping to improve the color of the product. In this he was successful, but says that, "from some unknown cause the white lead had a tendency to crystallize, and had therefore not sufficient body." This establishment was operated some five years, when it was destroyed by fire, and it has not been rebuilt. A small establishment was also erected during the decade in St. Louis, by Bacon and Hyde.

These additions to the facilities for the manufacture of white lead, together with the extension and more thorough establishment of the business of the Collier Company, of St. Louis, the enlargement of the plant of the Brooklyn Company, the purchase of the works of the Union Company of New York by Mr. James How and his associates, who changed the name to The Union White Lead Manufacturing Company, and the increase in the business of the Lewises, of Philadelphia, mark an important epoch in the history of the industry in America.

The lead fields of the Missouri and the Galena districts were at the zenith of their prosperity during this period, and produced more than sufficient to supply the wants of the country, but the method of transportation was crude, slow, and expensive. Mr. A. P. Thompson, of Buffalo, a son of the gentleman who established the manufacture of white lead in that city, furnishes an interesting account of some of the difficulties experienced in early days in procuring supplies of raw materials. The metallic lead was obtained by this house from the mines of the Galena district. The natural outlet for the metal was down the Mississippi to New Orleans, thence by sail to New York. The Buffalo manufacturers would then have to bring it up the Hudson,

and then by canal to Buffalo. They found it cheaper and more expeditious to bring their supplies across the prairies, from the mines to a port on Lake Michigan, and thence by sail to Buffalo. It was the custom of the smelters to offer the product of their furnaces daily, at public auction; this made it necessary for the Buffalo corroders to maintain an agent at the mines, to secure their supplies. When a purchase was made each pig of lead was stamped with a steel die, bearing a private device; when a sufficient quantity had been collected, a caravan of ox-teams was secured, and the train started on its lonely journey across the uninhabited prairies to Milwaukee, on Lake Michigan, where it was loaded upon sailing-vessels, and finally was landed at Buffalo. This method of transportation was naturally limited to the spring and summer months, when the cattle could gather their food on their journey; and the interruption in the receipt of supplies made it necessary to suspend operations at the Buffalo factory during the winter months.

The inventors seem to have been resting during this period. Smith Gardner, of New York, took out a patent in 1840, for a process by which granulated or small pieces of lead were introduced into vessels lined with sheet lead, and partially filled with water, and so arranged that they could be revolved or manipulated in such a manner as to subject the lead to continual attrition. The vessels were kept closed, and during the process carbon dioxide and air were introduced. This principle had been patented four years earlier in the United States, and two years earlier in England.

The same difficulty exists in estimating the volume of business in the United States during this period as has been noticed regarding the statistics of previous decades. It is probable that the annual production in 1850 was about nine thousand tons.

There was little development in the industry, so far as the erection of new plants is concerned, in the period included between the years 1850 and 1860. The universal custom of adulterating white lead with other white substances, and the development of the manufacture of zinc oxide, which was largely used as a substitute, left but little room, notwithstanding the continued increase of the country in wealth and population, for any phenomenal increase in the manufacture of white lead. William Wood of Cincinnati purchased the interest of Conkling in the Eagle Works, and associated with him T. J. McCoy. The Niagara White Lead Company was organized, and erected works at Buffalo. The manufacture had been established in a small way at Louisville, Kentucky, in 1840, but was unsuccessful, and the works were abandoned. In 1856, Wilson Waters and Company re-established the business and erected a new plant. In 1857 there were but three factories in Pittsburgh.

Several patents were issued during this period for improvements in the old process, or for modifications or substitutes; some of which, in the next decade, secured the support of capitalists in the effort to establish them. The older factories enlarged and extended their business, and the output in the United States in 1860, it is estimated, reached fifteen thousand tons.

The great development of the manufacture of white lead in the United States occurred in the period immediately following the close of the Civil War. The exigencies of the times at the beginning of the war occasioned a strong advance in the price of metallic lead, which checked for a time the use of white lead as a pigment. The high price of white lead and the large profits secured by manufacturers, owing to the large increase in value of their stocks, stimulated the erection of new plants at the termination of the war. Values of raw material now steadily declined,

enabling manufacturers to offer their productions at more reasonable prices. A strong public sentiment in favor of pure goods was fostered, resulting in driving adulterated articles from the market, with a consequent increase in the demand for white lead.

This period is marked by the foundation of several great establishments. In St. Louis, the business established by Blow in 1838 had grown to large proportions. In 1865 the St. Louis Lead and Oil Company, which succeeded the O'Fallon White Lead and Oil Company, was established, and in the same year Platt and Thornburg laid the foundation of the Southern White Lead Company. In Chicago, D. B. Shipman began to manufacture white lead, and the Western White Lead Company was organized; in Cleveland, J. H. Morley erected an extensive plant. Haslett, Leonard, and Company succeeded to the business of Waters in Louisville, and Lewis and Schoonmaker erected a new factory, which was afterwards sold to T. J. McCoy, who organized The American White Lead Company to operate it. Four factories were established in Pittsburgh, all of which may be termed offshoots from the establishment of Fahnestock and Company. In Cincinnati, Mr. Frederick Eckstein secured an interest in the business established by Townsend Hills in 1836, and Goshorn Brothers purchased the plant established by McCandless in 1828. This business was afterwards incorporated under the name of The Anchor White Lead Company. The Eagle White Lead Company, also of Cincinnati, was incorporated during this period. At Buffalo, the Cornell Lead Company was organized and succeeded to the business of The Niagara Company. Hall, Bradley, and Company, of New York, established the business in Brooklyn, now conducted by The Bradley White Lead Company, and Mr. Francis Brown organized The Salem Lead Company and erected extensive works at Salem, Massachusetts. The Maryland White Lead Company, of

Baltimore, was founded and an extensive plant erected in 1867.

No less than forty patents were issued in this decade for improvements in the manufacture of white lead ; some were for improvements in the manipulation of lead corroded in the old way, but generally these patents were for modifications of the Dutch method, or for the production of white lead by precipitation, or by other processes. None of the suggestions included in the specifications of these patents present any interesting features, except that proposed by Lewis and Bartlett, and none have proved to be of any economic value. Following English experimenters, our American investigators have applied all the resources of science and of invention to the subject, without securing any valuable result.

Lewis and Bartlett suggested the following: Finely divided metallic lead is mixed with carbon, and is subjected to the action of heat in a compound reducing and oxidizing furnace. The vapors, or fumes, are condensed and collected, and used as a substitute for white lead. This appears to have been the primary experiment, afterwards amplified and improved by these gentlemen, and the fumes arising from furnaces used for smelting lead ores were condensed, collected, treated to improve the color, and sold as *sublimed lead*, for use as a substitute for white lead.

Many attempts were made during this period to establish the manufacture of white lead in the United States by a quick process, but no important foothold was gained by any investigator. The production of white lead in 1870 has been estimated at thirty-five thousand tons.

The period included between the years 1870 and 1880 witnessed a continued development of the industry in America ; but this growth is principally noticeable in the increase in the facilities of the old and well-established factories. The Missouri Lead and Oil Company was

founded at St. Louis, but after a few years successful business its plant and business were acquired by its neighbors in St. Louis. McBirney and Johnston erected an extensive establishment in Chicago in 1879, but this has lately been absorbed by the Southern White Lead Company.

Thirty-five patents were issued for improvements in the manufacture of white lead during this decade. Of this number, but fifteen were for new methods or for improvements in processes suggested as substitutes for the Dutch method. Works for the establishment of the manufacture by these new processes were established at Taunton, Massachusetts; New Britain, Connecticut; Camden, New Jersey; Alliance, Ohio; at Philadelphia, Pittsburgh, New York, Baltimore, St. Louis, and at other cities; all were unsuccessful, and all have been abandoned and have entailed heavy losses upon their promoters. Experimenters have become wary, and capital can no longer be enticed into these fatal ventures. Lewis, of Philadelphia, perfected his plan for the manufacture of sublimed lead, and considerable amounts were produced at the smelting-works at Joplin, Missouri, and sold to the makers of colored paints.

The American investigator into the subject of providing a cheaper, better, quicker, and more rational method of preparing white lead than that practised by Theophilus and his predecessors, appears to have abandoned the field. During seven years ending with 1886 nine patents were granted for improved methods to English applicants, while but two Americans considered their suggestions of sufficient value to pay the fee. Several patents were granted for improvement in the management of the details of the Dutch process, relating chiefly to methods of washing and drying.

Since 1880, four establishments have been erected in the United States for the manufacture of white lead; of these but two are now in existence. The plants of F. W. Gerdes

and Brother and of the Washington White Lead Company, both of Pittsburgh, were destroyed by fire shortly after their erection, and have not been rebuilt. The older establishments, those well located and whose management has been conducted with vigor, have largely increased their facilities and their business, thus reducing the cost of production and rendering the establishment of new enterprises a hazardous undertaking.

The annual production of white lead in the United States at the end of the last decade may be placed at fifty thousand tons. In 1887 it is estimated that the output will reach sixty-five thousand, perhaps seventy thousand tons.

CHAPTER XVII.

LEAD OXIDES.

DEVELOPMENT OF THE MANUFACTURE.

IF metallic lead is heated to a temperature above its melting-point, and exposed to a current of air, it gradually absorbs oxygen, and becomes a coarse lemon-yellow powder. If the temperature is carried beyond the melting-point of this powder, it fuses into a crystalline scaly mass, which, upon cooling, breaks up into thin golden yellow laminae. These substances are known chemically as lead oxides, and their common or commercial name is "litharge," a word derived from the Greek, meaning, literally, "silver-stone," — a name given to it by the ancients on account of its production in the process of refining silver by the use of lead, and in the recovery of silver from the argentiferous lead produced by the first smelting of argentiferous galena. When ground in water, and dried, the lemon-colored powder becomes buff in color, and is the powdered litharge of commerce; the scaly powder is known commercially as "flake," or "glassmaker's litharge." The oxidation of lead for the direct production of these substances is usually conducted in furnaces of the reverberatory pattern, with continued stirring to constantly expose fresh surfaces to the air. Sometimes a revolving retort is used, when a mechanical contrivance secures the proper agitation.

Minium, or red lead, is considered to be a combination of protoxide of lead with a peroxide. It is made by mod-

erately heating, in a reverberatory furnace or revolving retort, litharge which has been ground and sifted, submitting it at the same time to a current of air, from which the heated litharge abstracts more oxygen, and changes its color from buff to a brilliant scarlet.

Orange mine, or orange mineral, is produced by moderately heating white lead in a reverberatory furnace, exposing it at the same time to a current of air. In this case the carbon dioxide is first expelled, leaving protoxide of lead, which gradually absorbs oxygen, producing red lead, generally of a lighter color than that made from litharge. Gmelin accounts for the difference in the tints of these substances by the different degrees of fineness in which they occur, the product of the oxidation of white lead being finer than that resulting from the oxidation of metallic lead. Litharge is said to oxidize imperfectly, and consequently red lead made from litharge generally contains a notable amount of the protoxide, while white lead oxidizes more completely and more rapidly, and the product is softer.[1]

The transformation of metallic lead into a dry powder by simply exposing it to heat in the presence of air, and its increase in weight during the operation — by the absorption of oxygen — astonished the ancients. The alchemists were perplexed by these phenomena, and persistently experimented upon lead in the endeavor to transmute base metals into gold. At a later time, an examination of the causes of these changes led to the discovery of oxygen.

Litharge was undoubtedly the first product of lead known to the ancients. Its formation in the process of cupellation has been described, and its discovery must bear as early a date as the invention of that process. The earliest evidence of the use of this substance in the arts is

[1] See Gmelin, Handbook of Chemistry, vol. v. p. 118; also Percy, The Metallurgy of Lead, p. 70.

found in the decoration and glazing of pottery recovered from the ruins of ancient Egypt and Assyria. The presence of lead oxides has been detected in analyses made of the paints which the ancient Egyptians used for glazing and for decorating pottery,[1] but no trace of lead has been found in the analyses of paints removed from the walls of tombs and monuments of these ancient nations; and if we accept this negative evidence, we must infer that the paints used by them for mural decoration consisted only of colored earths, and the salts of copper, iron, etc.

A perplexing confusion respecting the name of the substance we now know as minium, or red lead, prevailed in ancient times. Pliny quotes Theophrastus as stating that "minium was discovered in the year of Rome 439, by Callias the Athenian, who was in hopes to extract gold by submitting to the action of fire the red sand that was found in silver mines;"[2] but Theophrastus refers to cinnabar, the ore of quicksilver, from which we get our vermilion, and says "there are two kinds, — the one native, the other factitious; the native, which is found in Spain, is hard and stony, as is also that brought from Colchis, which they say is produced there in rocks and on precipices, from which they get it down with darts and arrows. The factitious is from the country a little above Ephesus; it is but in small quantities, and is had only from one place."[3] Vitruvius also improperly uses the term "minium." He says the best minium came from Pontus, near the river Hypanis, in the country between the borders of Magnesia and Ephesus; but he probably refers to an iron oxide, or to an earth colored with that substance, as he says "it is procured from the earth in such a state as to want neither

[1] Napier, The Ancient Workers and Artificers in Metal, p. 128.
[2] Pliny, Natural History, book xxxiii. chap. xxxvii.
[3] Theophrastus, History of Stones, p. 227 *et seq.*

grinding nor sifting, but is quite as fine as that which is ground and powdered by hand."[1] It has been suggested that the substance referred to by Vitruvius in this instance was the same as that called by Homer "miltos." But true minium, or red lead, was known to Vitruvius, as he says in another place that "white lead roasted in the furnace becomes changed by the action of fire into minium which is much better than that procured from mines."[2]

According to Pliny, minium was held in high estimation by the Romans in very ancient times. He says it was used in former times for sacred purposes. The face of the statue of Jupiter was painted with it. It was also used on festive occasions, and when victorious generals entered the city in triumph, their bodies were painted with this substance.[3] But the pigment referred to in this passage was undoubtedly cinnabar, which Pliny invariably terms minium. He mentions, in the same chapter, another variety of minium, which he says "is found in most silver mines, as well as lead mines, and is prepared by the calcination of certain stones that are found mixed with the metallic vein; not the mineral, however, to the fluid humors of which we give the name of quicksilver, — for if those are subjected to the action of fire they will yield silver, — but another kind of stone that is found with them. These barren stones may also be recognized by their leaden color, and it is only in the furnace that they turn red. After being duly calcined they are pulverized, and thus form a minium of second rate quality, known to but very few, and far inferior to the produce of the native sand we have mentioned," — that is, cinnabar. He further says: "If this minium is used on walls, it is affected by moisture; and this, too, notwithstanding the substance itself is a kind of metallic mildew."[4] Some

[1] Vitruvius, p. 215.
[2] Ibid., p. 212.
[3] Pliny, Natural History, book xxxiii. chap. xl.
[4] Ibid.

commentators regard these "barren stones of a leaden color" as galena, and the product after calcining as true minium or red lead. Davy, however, considered them to be the mineral cerussite, or native carbonate of lead.[1]

Pliny describes a method of heating or melting ceruse in shallow vessels, with constant stirring with ladles until it became red and assumed the appearance of "sandarach," — meaning, probably, realgar, a salt of arsenic which has been used in modern times as a pigment. Pliny says this burnt white lead — *usta* as he termed it, *cerussa usta* as it is generally termed by ancient writers — was discovered by an accident. At a fire which occurred in the Piraeus, the port of Athens, there happened to be stored in one of the houses which were consumed a quantity of white lead, packed in earthen jars. After the fire, the ceruse was found to be changed in color to a brilliant scarlet. One author asserts that the ceruse was in the apartments of a lady by whom it had been used as a cosmetic. The product of this accident was seized upon by Nicias, a celebrated painter, as a new pigment, and he is said by Pliny to have been the first to use it for this purpose. Pliny also states that in his day the variety which came from Asia, and was known as "purpurea," was considered to be the best. These statements are intelligible enough, and point to the *cerussa usta* of the ancients, burned white lead, — our "mine orange," or "orange mineral," — as the substance referred to; but Pliny, continuing, says: "It is also prepared at Rome by calcining 'marbled sil,' and quenching it with vinegar." Sil is described by Pliny as "a pigment found in mines of gold and silver, and is, properly speaking, a kind of slime."[2] Commentators upon this passage are of the opinion that sil was an argillaceous earth, colored with

[1] Davy's Collected Works, vol. vi. p. 138.

[2] Pliny, Natural History, book xxxiv. chap. liv. and book xxxv. chap. xx., xxxv.

iron ochres of various shades of yellow and of brown. The connection by Pliny of the substance prepared at Rome from sil with the true usta prepared from white lead, and the coincidence of names, is another example of the obscurity and inaccuracy of Pliny, or of the ignorance which prevailed at the time respecting the properties of many substances used as pigments.

Pliny's description of the method of preparing *cerussa usta* covers all the essential points of the modern method of making orange mineral; but besides *cerussa usta,* this product was known in his time as *sandyx* and *syricum.* As has been observed, the name "minium" was first applied to cinnabar, — mercuric sulphide, — and the source of our vermilion; but this substance becoming subject to adulteration with *cerussa usta,* the name "minium," after being long used to designate both cinnabar and red lead, was at last applied only to the latter substance.[1] Pliny and other ancient writers refer to "spuma argenti," the scoria or scum of silver. Pliny mentions three varieties of this substance: that most in favor was known as "chrysitis," the second best was called "argyritis," and the third bore the name "molybditis." The distinction between these varieties appears to have been one of shade of color only, as Pliny says that "in some instances all these tints are to be found in the same cake." The most approved kind, Pliny states, was produced in Attica; the next in favor came from Spain. *Chrysitis* was "the produce of the metallic vein;" *argyritis* was obtained from the silver itself; while *molybditis* was produced in smelting lead at the works at Puteoli. Pliny describes the methods employed in producing these substances, as follows: "The metal is first melted, and then allowed to flow from a more elevated receiver to a lower one; from this last it is lifted by the aid of iron spits, and is then twirled round at the end of

[1] Theophrastus, History of Stones, note by Sir John Hill, p. 227.

the spit in the midst of the flame, in order to make it all the lighter; thus, as may be readily perceived from the name, it is in reality the scum of a substance in a state of fusion."[1] In another chapter Pliny describes molybdena, which he also calls galena, as a mineral compounded of silver and lead; "it is considered better in quality," he says, "the nearer it approaches golden in color, and the less lead it contains; it is also friable and of moderate weight; it is found adhering to furnaces in which gold and silver have been smelted, and in this case it is called metallic. The most esteemed kind is that prepared at Zephyrium,"[2] in Cilicia.

In these statements Pliny refers unquestionably to varieties of litharge, — the yellow and the flake litharge, sometimes called golden, — though some authorities are of the opinion that in the passage where he treats of molybdena, he refers to Roman stannum; but he mentions its color as being sometimes near golden, and that it was friable, — which describes litharge very accurately, and is not at all like Roman stannum.[3]

The localities mentioned by Pliny, where litharge was procured, may perhaps afford a clue to the principal seats, in his time, of the production of silver by the process of cupellation; which were in Greece, in Spain, and in Cilicia. It is probable that the stannum produced at the furnaces of some of the mines was desilverized by cupellation at Puteoli, as Pliny says the Puteolian variety was the result of smelting lead. Puteoli was an important seaport of Campania, and was the chief emporium for the commerce with Spain.

In Matthioli's edition of Dioscorides, *spuma argenti* is

[1] Pliny, Natural History, book xxxiii. chap. xxxv.

[2] Ibid., book xxxiv. chap. liii.

[3] Ibid., book xxxiv. chap. liii., note; also Beckmann, History of Inventions, etc., vol. ii. p. 211.

described as produced by heating to incandescence in a furnace, "sand which they called leaden." Another variety was produced from silver, and a third from lead. That most preferred was produced in Attica; the next best variety was the Spanish; while that made at Puteoli, in Campania, and in Sicily, was made by heating laminae of lead, and seemed to hold the lowest place in the estimation of the writer. That which possessed a brilliant yellow color was termed *chrysitis,* and was esteemed the best; that made in Sicily was called *argyritis,* and that produced from silver was termed *calabritis.* The *spuma argenti* produced from the sand which they call leaden may refer to some substance other than litharge; but there is no question respecting the other varieties, particularly that described as made from lead. The *spuma argenti* produced from silver was undoubtedly lead oxidized in refining the noble metal, and litharge is the substance referred to.[1] Litharge produced in refining silver continued to be known by the name *spuma argenti,* or "the scum of silver," for many centuries. Agricola, writing in the sixteenth century, applies the term to the oxide of lead produced in the desilverizing of argentiferous lead; and Matthioli, in a chapter headed "Molybdena, or Plumbago," says: "Molybdena is, like *spuma argenti,* reddish yellow, moderately bright, and when rubbed, is yellow, when digested with oil it acquires a liver color. It is generated in furnaces containing gold and silver."[2] Beckmann says the first author in whose writings he has found certain mention of plumbago, or graphite, is Gesner, who mentions its use in a work published in 1565;[3] and surely Dioscorides, in the above paragraph, does not describe the mineral graphite. This is another instance of the provoking confusion of names; and to increase the

[1] Dioscorides, Matthioli's Commentaries, p. 666. [2] Ibid., p. 665.
[3] Beckmann, History of Inventions, etc., vol. ii. p. 390.

perplexity, Sprengel, whose edition of Dioscorides is considered to be the best, heads this chapter "Galena;" but he substitutes the term "litharge" for *spuma argenti*. Dioscorides further states that there was a certain mineral found near Sebosti and Corycus, of which the most approved examples were yellow and shining, and had properties similar to *spuma argenti*. It was washed and purified in a similar manner. The litharge of that time was probably produced almost entirely in the process of purifying the noble metals. Its production directly from lead was doubtless practised in a small way only. Dioscorides describes several methods of preparing *plumbum ustum*. In one case he recommends its preparation by heating fine laminae or shavings of lead, mixed with sulphur, in an iron or earthen vessel, stirring meanwhile with an iron rod until it is reduced to ashes. Sometimes barley was added in place of the sulphur, or ceruse was occasionally so employed. What is described as a more difficult method of producing litharge is "burning the lead without the admixture of any other substance;" but when this was completely done "it resembled *spuma argenti*, or litharge, in color." [1]

This is the earliest notice of the production of litharge, as a primary product, from metallic lead. All former references to this substance treat of it as a by-product in the cupellation of argentiferous lead, or describe its production in the purification of silver or gold by the aid of lead.

In ancient times the preparation of red lead by reheating litharge seems to have been unknown. *Cerussa usta*, our orange mineral, was used in all cases where red lead was required. Dioscorides says ceruse is roasted in the following manner: "Put a new earthen vessel, best of all an Attic one, over coals; sprinkle in it powdered ceruse, stir constantly, and when it shall have acquired the color

[1] Dioscorides, Matthioli's Commentaries, p. 662.

of ashes, remove and cool and so use it. But if you desire to burn it, place it powdered in a hollow platter, and having set this on the coals, stir with an iron rod until it attains the color of sandarach; then take it out and use." [1]

Dioscorides describes litharge under the names of *molybdena* and *spuma argenti*, the product of cupellation, and also by the name of *plumbum ustum*, burnt or roasted lead; while for red lead he adopts the *cerussa usta* described by Pliny, and recommends the treatment of white lead by fire. He says that *argentum vivum*, by which he means quicksilver, is made from *minio*, — *minium*, Pliny's name for cinnabar. Notwithstanding this misapplication of names, Dioscorides appears by his descriptions and statements to have had a clear idea of the properties of these bodies, of the substances from which they were derived, and of the methods employed in their preparation.

Minium was in use in the time of Vitruvius and Pliny for interior decorations. It is constantly referred to by writers of that period; and from the very general custom of elaborate interior decoration, it was doubtless used in considerable quantities. Vitruvius tells us that the ancients decorated their interior walls with pictures of men, horses, ships, etc., often very elaborately executed, but in proper taste; whereas in his time the public taste leaned towards strong and gaudy coloring; and for the effect which was formerly obtained only by the skill of the artist, "a prodigal expense is now substituted." "Who, in former times," he continues, "used minium, except in medicine? In the present age, however, walls are everywhere covered with it." [2] In this passage Vitruvius refers to cinnabar, which was much more valuable than *cerussa usta;* but this latter substance, our orange mineral, was well known and much used, both as a substitute for, and as an adulterant of, the more expensive cinnabar. Among

[1] Dioscorides, Matthioli's Commentaries, p. 667. [2] Vitruvius, p. 212.

the substances found in a vase discovered in excavating in the baths of Titus, Davy detected red lead; and a deep yellow, which covered a piece of stucco found in the ruins near the monument of Caius Cestius, proved upon analysis to be lead oxide, and consisted of litharge mixed with red lead. Davy detected the presence of red lead in several analyses of colors found in the ruins of ancient Rome; and he thought that the pale sandarach, said by Pliny to have been found in gold and silver mines, and which he says was imitated in Rome by a partial calcination of ceruse, must have been litharge, the yellow oxide of lead, or that substance mixed with red lead.[1]

The term *minium* was still applied to cinnabar and to other native red pigments in the seventh century. Isidore, of Seville, probably refers to cinnabar when he says that "minium was first found near Ephesus, but it is more abundant in Spain." He also states that minium was produced in the separation of silver from argentiferous lead. Possibly this was classed by him, as by Pliny, as minium of second quality. Isidore, of Seville, describes sandarach as a production of the island of Topazo in the Red Sea. Pliny refers to this source of sandarach, by which name he possibly indicates a salt of antimony or of arsenic. A spurious kind, he says, was prepared by calcining ceruse in the furnace.[2] Isidore, following Pliny as usual, tells us that sandarach was produced by subjecting ceruse to heat; and that if it was heated a second time it acquired a flame color.[3]

In Geber's writings red lead is termed "zinnobars." Albertus Magnus and other alchemical writers followed Geber in this and used the same term.

In the middle ages minium was rarely confounded with

[1] Davy's Collected Works, vol. vi. pp. 135, 139.

[2] Pliny, Natural History, book xxxv. chap. xxii.

[3] Eraclius, De Coloribus, etc., Original Treatises, etc., vol. i. p. 254.

native cinnabar, which seems to have been neglected as a pigment, while artificially prepared vermilion was much used. Eraclius mentions vermilion, and directs the artist to mix it with white lead "to make the color called rosa."[1] Theophilus and Saint Audemar describe the process of making vermilion from quicksilver; Cennini says it is made in an alembic, by a chemical process "too tedious to describe, but for which, if you desire to labor at it yourself, you may find many recipes, especially among the friars."[2] The methods employed in its preparation were well known in the eleventh century, and after this period we are no longer in doubt as to the substance referred to by writers who treat of minium.

According to Eraclius, "to make red minium, you must put ceruse in a jar, and place it on the fire and keep stirring it until it becomes red. If you cease stirring, it will turn back to ceruse."[3] Theophilus describes its manufacture in much the same manner: "You must grind ceruse upon a stone without water, and then placing it in two or three new pots, put it upon hot coals, stirring it from time to time with a curved iron rod, curved at one end and flat on top and provided with a wooden handle. You must heat and stir it until the minium becomes quite red."[4] The compiler of "Mappae Clavicula" adds a recipe for making minium as follows: "Pulverize ceruse thoroughly; heat it over coals, stirring all the time if you wish to make it red, after which set it aside to cool."[5]

These authors do not mention the manufacture of minium from metallic lead; they describe the manufacture of what the Romans termed *cerussa usta*, — our orange mineral. They do not refer to litharge as a pigment in

[1] See Theophilus, Hendrie, p. 420; also Mrs. Merrifield, Original Treatises, etc., vol. i. p. 138.

[2] Cennino Cennini, p. 23.

[3] Eraclius, De Coloribus, etc., Original Treatises, etc., vol. i. p. 236.

[4] Theophilus, Hendrie, p. 49.

[5] Mappae Clavicula; Archæologia.

common use, although they were acquainted with the production of this substance in the purification of silver. Theophilus, however, describes the composition of a color to be used in painting faces, as follows: "Take ceruse and put it dry and without grinding into a copper or iron vessel, place it upon glowing coals, and burn it until it is converted into a yellow color; then grind it and mix it with white ceruse and cinnabar until it is converted into a color like flesh."[1] Theophilus gives no name to the substance resulting from this process. It is almost precisely like his description of the manufacture of minium; and undoubtedly litharge, or partially decarbonized white lead, is the product desired, and would result if the oxidation was not carried too far; grinding would impair the color and make it buff if it was thoroughly oxidized.

After the revival of art in Italy, minium was much in favor with artists. The compilers of formulae and recipes of the latter half of the middle ages do not fail to mention it frequently, and to give — sometimes with great care and minuteness — directions for its preparation. Petrus de Sancto Audemaro says: "You may convert the white color, which is called ceruse by the armourers, into minium by putting it into a jar and torrefying it over the fire for two days and two nights, stirring it frequently in the vase or jar with any instrument. And this is the way to make minium. Take care not to let any flame get inside the jar; but make the fire of charcoal only, without flame." The charcoal should be large, so that the air may pass through the spaces of it and keep up the heat; it should not be small, for then it would be useless. When it begins to get hot, stir the color which is inside with a spoon or ladle, a strip of brass or iron, so that the hot color which is next the side of the vase may be mixed with the tepid part in the middle; for this stirring is the principal cause

[1] Theophilus, Hendrie, p. 3.

of the perfect preparation of all which is thus torrefied; and this stirring must be repeated four or five times every two or three hours. This process must be conducted for two days and two nights following, not sleeping all the time, unless you have another to supply your place and to continue stirring and to take care of your fire, or your labor will be in vain."[1]

The author of this description uses the term "sandaracca" as synonymous with "minium;" he says, "If I am not mistaken, minium, that is, sandaracca, and white lead, that is, ceruse, are of one nature. If you put ceruse into the fire it takes a new name and color and strength, because the more it is burned the redder it is; and the less it is burned the more it retains its former color, that is, its whiteness or its paleness. In laying it on walls it is ground with gum-water, but never with egg. It can, however, be laid upon parchment distempered with egg, but on wood it must be mixed with oil."[2]

Cennini was of the opinion that minium should be used only in pictures. If it was used on walls, on exposure to the air he says it suddenly became black and lost its color.[3]

In the formulae of the later manuscripts an important departure from the methods described by earlier writers may be noticed. Ceruse is no longer the only substance recommended to be used for the production of minium. In the collections of recipes entitled "Segreti per Colori," of the fifteenth century, it is recommended that calcined litharge and lead be prepared together over the fire;[4] and Le Brun says: "Minium is made of lead melted in an earthen vessel over the fire, and stirred with a stick until the whole is changed into minium, which is found attached

[1] St. Audemar, De Coloribus Faciendis, Original Treatises, etc., vol. i. p. 124.
[2] Ibid., vol. i. p. 140. [3] Cennini, p. 24.
[4] Mrs. Merrifield, Original Treatises, etc., vol. ii. p. 484.

to the side of the vessel." This author also says that if white lead is heated in a furnace its color will be changed and it will be converted into sandaracque or massicot.[1]

These authors describe methods of purifying minium by grinding and washing it carefully several times with fresh water. They recommend several vehicles for applying it, — water, honey, and gum-water, as well as linseed oil.

While minium, or red lead, was not confounded with cinnabar in the latter part of the middle ages, the confusion regarding its name which existed in Pliny's time continued with little abatement for several centuries. Vitruvius and Dioscorides termed *cerussa usta sandaracca*, and the compilers of the manuscripts which have been referred to use the same term with frequently slight changes in the orthography. Matthioli says: "Formerly, according to Galen, *sandyx* was made by burning ceruse," and Dioscorides speaks of treating arsenic by heat, by which "one gets the common officinal minium."[2] The Spanish name for minium was *azarcon*. In Italy it was known as *sandaracca, sandyx*, and as *sandice*. Its names in Arabic were *afrengi, sarchon, sandicon, syrengi, serengi*. In the Mt. Athos manuscript it is termed *lampezi*.[3] It was known as "minio," and "mine," and when washed and purified, it is supposed to be the color known to painters in the middle age as "saturnine red."

Litharge, as before mentioned, is noticed but rarely in the manuscripts of the middle ages. Possibly it was not in favor as a pigment earlier than the fourteenth and fifteenth centuries. Le Begue, in his table of synonymes, tells us that *flavus color* is made by burning ceruse,[4] and

[1] Pierre Le Brun, La Peinture, etc.; Mrs. Merrifield, Original Treatises, etc., vol. ii. pp. 804, 806.

[2] Dioscorides, Matthioli's Commentaries, p. 665.

[3] Didron, Manuel d'Iconographie Chrétienne, etc., p. 47.

[4] MS. of Le Begue; Mrs. Merrifield, Original Treatises, etc., p. 26.

Cennini says there is a yellow color, called *arzica*, which is the produce of chemistry and is little used.[1] Litharge is possibly the substance referred to in these statements.

In the manuscript of Le Begue litharge is referred to as *sandaraca*, and is said to be of the same nature as minium and ceruse, and that when heated these substances change their name, strength, and color.[2] In the Marciana manuscript entitled "Secreti Diversi," the preparation of "burnt lead," to be used in the manufacture of glass, is described. Lead is placed in a vase over a fire strong enough to liquefy it; when in a molten state the mass is skimmed, and the skimmings are afterwards refined by putting them in another vase, which is heated, and the contents are stirred until all is thoroughly calcined. The substance produced was litharge.[3]

The *giallolino* of the Italian painters of the sixteenth century was probably litharge, though considerable confusion existed respecting its name. Some writers term it *giallolino di Fiandra*, or *giallolino di Alamagna*, from which it is inferred that it was produced in Flanders and Germany, and brought thence to Italy. One variety was called *giallolino fino*, which was also probably litharge, but another, which was prepared at Venice, appears to have been composed of *giallolino fino* and *giallolino de vetro*; this latter substance was composed of lead and tin melted and calcined. Naples yellow, called *giallolino di Napoli*, was composed of the oxides of lead and of antimony, and was originally prepared at Naples. This color is referred to by Cennini, who says it is a real stone found in mountainous volcanic districts; therefore, he says, "it is an artificial pigment, but not a chemical production. It is, however, artificially prepared by a secret process in Italy."

[1] Cennino Cennini, p. 28.

[2] Mrs. Merrifield, Original Treatises, etc., vol. i. p. 314.

[3] Ibid., vol. ii. p. 614.

Mrs. Merrifield thought that there were two varieties of *giallolino di Napoli*, one a native mineral pigment, and the other artificially prepared.[1] Merimée says of *jaune de Naples*, "The discovery of this color must date from a high antiquity, the epoch of the making of enamels." This pigment was composed principally of lead oxide, with the addition of antimony and other substances in varying proportions.[2]

Litharge has borne many names. In Greece it was termed *lithargyrus;* Pliny and other early writers term it *spuma argenti;* the Arabian names mentioned by Matthioli are *martech* and *merdasengi;* it was called *almartaga, genuli, litargino,* and *yezes de oro,* in Spain. Matthioli says if it contained much silver it was called "litharge of gold;" if less it was termed "litharge of silver." These names evidently were given on account of its color, which varies according to the degree of heat to which it has been exposed. In Italy in the middle ages litharge was called *giallolino fino, giallolino di Fiandra, giallolino di Alamagna, luteolum Belgicum,* and *massicot.* Jehan le Begue refers to it as *flavus color.* In France it was called *fin jaune;* in the Paduan manuscript it is termed *gialdo di piombo,* and *gialdolino;* in the Bolognese manuscript it is called *terragietta* and *litargirio;* Volpato refers to it as *retargirio,* and Le Brun terms it *sandaracque, fin jaune,* and *litarge.*[3] An English writer of the seventeenth century calls red lead "mene," and litharge "masticote."[4]

In a curious "Collection of Scarce and Valuable Treatises," published in London in 1738, is a treatise upon "The Art of Metals" by Alonzo Barba, a Spanish priest.

[1] See Mrs. Merrifield, Original Treatises, etc., vol. i. p. 156 *et seq.;* also Cennino Cennini, p. 26.

[2] Merimée, De La Peinture à l'Huile, p. 110.

[3] See Mrs. Merrifield's Original Treatises, etc., vol. i. p. 26, vol. ii. pp. 536, 705, 741, 817; also Dioscorides, Matthioli's Commentaries, p. 667.

[4] Sanderson, Graphice, p. 55.

Barba says, " Sandix [meaning red lead] is made of *albayalde* [white lead] burnt in the fire, which some improperly call *sandaracca*." This substance, he explains, " is only orpiment well concocted."

In the oxidation of metallic lead the products take different shades or tints, depending upon the intensity of the heat, the time consumed in the operations, and other circumstances. This explanation will satisfactorily, perhaps, account for much of the confusion respecting the name of this substance which existed prior to the seventeenth century, and for the apparent contradictions of the early writers who treat of this subject.

The aggressive character of the Dutch manufacturers of the sixteenth and seventeenth centuries led them to engage largely in the manufacture of lead oxides. Encouraged by their success in driving Venetian white lead over the Alps, they strove to monopolize the trade in oxides; but since they procured their raw materials from other countries where these oxides were a by-product in the purification of argentiferous lead, their enterprise could not counterbalance their disadvantageous location. We find, therefore, that in the seventeenth century the English manufacturers competed with them, supplying the increasing demand for these substances at lower prices than the cost of production to their less favorably situated neighbors. They treated the litharge produced in cupelling their argentiferous lead, and exported the product in large quantities to all parts of Europe.

In 1622 Christopher Eland received a patent by the provisions of which the patentee " shall take and receive from makers, if they will continue to make the same, such a quantity of redd leade as may bee conveniently sould within this our realme of Englande yearly, paying soe much as himselfe and others have paid heretofore, according to such quantitie and porc̄ons as the fower work-

houses nowe ymployed for the making thereof (Christopher Eland being one) doe nowe usuallie make by equal porc̄ons." It appears from the terms of this specification that at that time there were four establishments engaged in the manufacture of red lead in England. The patent seems to have been simply the grant of a monopoly of the traffic in red lead in England. Eland possibly enjoyed this monopoly for twelve years. The letters-patent were surrendered in 1634.[1]

In 1670 Sir John Pettus mentions the red-lead mills of the mines in Cardiganshire, in which eleven men were employed.[2] In a report of a commission in 1708 it is stated that two furnaces for making red lead existed in Glamorganshire.[3] Smith, writing in 1676, directs that litharge should be made out of common lead and then should be ground and treated in a hot furnace with constant stirring; the product, red lead, he says, is the only color used to make drying oil.[4] Pomet says of this substance: "The red lead which we call minium is lead ore pulverized, calcined, and reduced to such a powder as we see. It is wrong to think that the red lead which is brought from England is made of pig-lead; the cheapness of it shows it to be otherwise, and that it is made of lead ore as it comes from the mines; besides, pig-lead will never come to that redness as

[1] Abridgments of Patents, etc., p. 1. Monopolies were common in England in the sixteenth century. The necessities of the crown led the king to grant such favors for a money consideration, and the policy of the times dictated the restriction of certain trades or manufactures within particular limits. Merchants were granted a monopoly of the sale of certain goods or wares and the manufacture of some articles was restricted by law to certain towns. Early in the seventeenth century, however, this restriction of commerce became so intolerable that the people demanded the abolishment of all monopolies; and in 1624 an edict was published declaring all monopolies, with the exception of certain patents, null and void.

[2] Quoted by Hunt, British Mining, p. 154.

[3] Grant-Francis, Smelting of Copper in the Swansea District, etc. (London, 1881), p. 84.

[4] Smith, Painting in Oyl (edition of 1676), p. 21.

lead ore, whatever fire you give to it."[1] As France in that day produced little or no metallic lead, it is probable that Pomet was unaware of the fact that in the desilverization of lead in England litharge was produced in quantities far in excess of the demand in that country, and that the English smelters were only too glad to dispose of this substance at prices considerably less than the value of metallic lead, rather than to reduce it by treatment in a blast furnace. Pomet also seems to have been ignorant of the fact that it is necessary to reheat litharge to produce red lead. While the Dutch lost their trade in litharge, they seem to have retained their position as manufacturers of Pliny's *cerussa usta*, our orange mineral. Huet refers to this fact.[2] Pomet distinguishes the difference between red lead and orange mineral. He says, "*Sandyx*, or red ceruse, is nothing but ceruse reddened over a gentle fire." It was but little used in his time, and he claims that the writers who state that minium was made from white lead are in error; as white lead came from Holland, while minium came from England and was cheaper than ceruse.[3] Pomet, it will be observed, gives the old name, *sandix*, to our orange mineral. Lemery, who edited Pomet's work, observes that red lead is called minium from the word "mina," "because it is made of lead as it comes from the mine."[3]

Pomet states that *masticot* is of three sorts, "depending upon the degree of fire to which they give the powder of white lead. The least heat gives the white (which is not white but yellow), the second has received a stronger degree of heat; the third, a gold color, has been subjected to a strong fire, a fourth has been yet longer treated and is called *sandyx*."[3] Von Justi says that massicot is made from bleyweiss — white lead — by allowing a flame to pass

[1] Pomet, A Compleat History of Druggs, p. 124.

[2] See Huet, Review of the Dutch Trade.

[3] M. Pomet, A Compleat History of Druggs, p. 124.

over it while it is stirred, and is of many tints, yellow, yellow-red, and red. He states that it was very expensive, and in the end no better than *bleygelb* and *menige*, meaning litharge and red lead made from metallic lead.[1] Massicot was at that time distinguished from litharge, probably as being the product of the oxidation of white lead at a heat sufficient to drive off the carbon dioxide, but insufficient to effect the complete oxidation necessary to produce red lead.

Savary, in his "Universal Dictionary" (1751), gives a very clear description of the manufacture of red lead, and shows that he fully understands the process he describes. He says we are first to melt lead in a broad vessel, with constant stirring, until it is calcined to a gray powder; the stirring should be continued, when it will change to a yellow and become the *masticot* of commerce which is used in painting. "If this masticot be then calcined in a reverberatory furnace," he says, "it will change its hue to a fine red color and become the common minium."[2] Von Justi refers to the manufacture of red lead in England, Holland, and in Nuremberg, and says it is produced by the action of fire upon litharge in red-lead furnaces. He says it cannot be made from galena without first driving off the sulphur, "which is a needless thing to do when we have so much litharge and other suitable materials at hand,"—referring probably to the litharge which was a by-product in the process of cupellation. The furnace, he tells us, "must be of a form especially adapted to the purpose; the fire must be on both sides, and kept up with wet wood which gives a great smoke; the smoke and the flame must come in direct contact with the litharge, which must be constantly stirred." He has seen it stated, he says, that common salt added to the litharge produces a very

[1] Von Justi, Vollständige Abhandlung von den Manufacturen, etc., p. 518.

[2] Savary, Universal Dictionary, p. 4.

fine color, but of this he is not able to speak from experience.[1] This statement of Von Justi of the methods employed in the manufacture of red lead is quite in accordance with modern theory, save that it is no longer considered necessary to employ wood as the fuel. The same author, however, some years later modified his views, as will be seen by the following extract: "The Dutch have a monopoly of the trade in red lead, and manufacture it by a secret process which they guard with great care, not allowing any stranger to enter their factories. They make it from galena, which they get very cheap from all regions of the earth where their ships go, which bring it home as ballast." He claims to have experimented with litharge in the manufacture of red lead and failed to get any color with it, but succeeded with galena. He says it is necessary to use poor and wet wood for burning it, so that a thick smoke shall pass over the ore for a considerable time. "Doubtless," he says, "it mixes with it; at all events you cannot get the color without the smoke." "The furnaces must be constructed so that the flame shall pass over the ore, and the material should be constantly stirred." At this time, according to this author, the use of red lead was quite universal throughout Europe, where it was used to paint wagons and wooden utensils."[2]

Many authors of this period mention the trade in lead oxides in England. Macpherson refers to the shipment of this substance from Newcastle, and Pennant says that the shipments from Chester from 1758 to 1777, as taken from the books of the custom house there, show an export of two thousand seven hundred and sixty-seven tons of litharge.[3] Watson states that the flint-glass makers in-

[1] Von Justi, Vollständige Abhandlung von den Manufacturen, etc., p. 518.

[2] Berghauptmann Von Justi, Chemische Schriften (Berlin, 1771), vol. iii. p. 121.

[3] Pennant, A Tour in Wales, vol. i. p. 203.

formed him that "the red lead made from litharge did not flux so well as that made direct from lead." In his time (1780) there were nine red-lead furnaces in Derbyshire. He states that the manufacture of red lead was very well understood in England and in Holland, but that the French workmen did not succeed so well, and thought it could not be made by the flame of wood fires.[1]

The manufacture of red lead and litharge is now established on an extensive scale in England. The process is conducted in furnaces of the reverberatory pattern, — the lead being converted in the first operation into litharge, which is ground and dried, and is then charged into a furnace of similar construction, where it is heated in the presence of atmospheric air, and is converted into red lead. The modern method used in the manufacture of lead oxides is elaborately treated by Percy and other writers on the chemistry and technology of the metals.

The manufacture of lead oxides in the United States was begun as early as the first decade of this century at Philadelphia. Bishop says that three factories for the production of red lead existed in that city as early as 1810, and it is probable that the manufacture of lead oxides was begun before the erection of works for making white lead. There are no establishments in this country devoted exclusively to the manufacture of lead oxides, but makers of white lead have generally added to their plants apparatus for the production of this substance. The methods commonly employed in the United States are the same as described by Savary more than a hundred years ago. In some instances, however, the reverberatory furnace has been replaced by an iron bottle-shaped cylinder, called a retort, open at both ends and made to revolve slowly by means of a geared wheel. The inside of these cylinders is provided with longitudinal ribs, which serve, as the cylinder revolves,

[1] Watson, Chemical Essays, vol. iii. pp. 339, 343.

to keep the material thoroughly stirred. The retort is charged through the aperture at the front. The rear end is connected with the chimney by a pipe, and a constant circulation of air is thus provided, to which fresh surfaces of the heated metal are continually exposed by the stirring action of the interior ribs.

Red lead is manufactured in India and in China, where it is used in considerable quantities in glass-making, in painting, and in the decoration of pottery. The Hindus attach great importance to this pigment, believing it to possess supernatural attributes. They smear it upon their idols, paint their rupees with it for good luck, and rub it upon a stone to convert it into a *dev*, or object of worship.[1]

Authorities differ respecting the date of the invention of the process for glazing pottery with lead. By some it is said to have been introduced into Europe in the fourteenth century by the potters of Tuscany and Romagne, who borrowed it from the Saracens in Spain; others contend that a potter of *Schélestadt* practised the art as early as 1283. Kopp says that earthenware was glazed with lead in the fourth century;[2] but Faraday in 1847 examined the glazing removed from a vase of undoubted Roman manufacture found in Surrey, England, and pronounced it to consist of lead carrying a small amount of silver, probably accidentally present in the lead.[3] Schliemann found at Mycenae objects resembling buttons, which proved upon analysis to be composed of "a strongly burned clay varnished with a lead glazing." He thought they had been used as ornaments for the house doors or other places.[4] It has been stated that the glazing of pottery found in ancient Egyptian tombs is composed of lead; and there is reason to believe that the glazing of bricks and other articles

[1] Cyclopædia of India, article Lead.
[2] Kopp, Geschichte der Chemie.
[3] Archæologia, vol. xxxii. p. 352.
[4] Schliemann, Mycenae, pp. 76, 108.

found at Nineveh and Babylon was produced in some cases by the use of litharge. Maigne states that the art was invented in the East, and is supposed to have been known in the time of Solomon,[1] and the researches of modern archaeologists seem to confirm this suggestion. Eraclius, whose manuscript is attributed to the ninth or tenth century, describes the process minutely, and gives directions for producing a variety of colors and tints in the glaze.[2] The use of lead in the form of oxide in glazing earthenware is mentioned by many writers of the middle ages, and until the introduction of the method of glazing with common salt, which dates, according to Maigne, to 1690,[3] it was, with the exception of the use of pure galena, — called potters' ore, or alquifoux, — the only method practised.

The remarkable property of litharge of forming fusible compounds with nearly all the metals was known at a very remote period, and the early metallurgists took advantage of this peculiarity in their methods of purifying the noble metals. The principles discovered and employed by them are in use to-day, and lead oxide is an invaluable substance for such purposes. The second source of lead referred to by Pliny is the reduction of litharge to metallic lead by treating it mixed with fuel, in a furnace. Diodorus, quoting Agatharchides, refers to the purifying of gold by mixing with it lead, barley bran, and other substances, and heating it in a furnace;[4] barley bran was doubtless added as a carbonaceous material, to serve as fuel, as was frequently the custom with the ancients. The alchemists likened the oxidation of metals to death, and the process of deoxidation — or the recovery of the

[1] Maigne, Dictionnaire Classique, p. 334.

[2] De Coloribus et Artibus Romanorum, Mrs. Merrifield, Original Treatises, etc., vol. i. p. 206.

[3] Maigne, Dictionnaire Classique, p. 335.

[4] Diodorus, vol. i. p. 159.

metal from its ores or from a compound — to a revival of life; hence when an oxide was reduced to the metallic state the metal was said to be revived. This process was conducted in a furnace, and wheat was often mixed with the oxide, perhaps to serve as fuel, as charcoal is in modern times. The combustion resulted in dispelling the oxygen and in liberating the metal. It was this circumstance, it is said, that caused wheat to be regarded as the symbol of the resurrection and of eternal life.

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